SUSTAINABLE LIVELIHOODS AND FOOD AND NUTRITION SECURITY OF KENYAN SMALLHOLDER FARM WOMEN

BY

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Abstract

There is limited scientific information on relationships among smallholder dairy group membership duration, sustainable livelihoods, food and nutrition security in developing countries, and whether nutrition education of women dairy farmers enhances the nutritional benefits of being a dairy group member.

The objectives of this thesis research were: 1) to identify associations among sustainable livelihood (SL) measures and dairy group membership duration; 2) to identify determinants of food and nutrition security; 3) to determine effects of a nutrition education intervention; and 4) to explore factors influencing food choices to help explain intervention results.

A cross sectional survey was used to collect data from smallholder farmers in Kenya. Wakulima Dairy (WDL) members (n=88), across four membership duration groups (1-3, 4-6, 7-9 and 10+ years), and non-members (n=23) were interviewed about SL assets (human capital e.g. education, household size; physical capital, e.g. livestock, consumer assets; natural capital e.g. land holdings; social capital e.g. women's group affiliation), and outcomes (e.g. income, food and nutrition security). Members and non-members were randomly assigned to nutrition education intervention and control groups and re-interviewed five months post-intervention to assess nutrition security and factors influencing food choices.

SL assets and outcomes were described and associations among these measures and membership duration examined. Determinants of food and nutrition security were identified among SL measures. Pre- and post-intervention nutrition knowledge and diet quality indices were compared and examined for an interaction of membership and intervention status.

Dairy herd size, per-cow daily milk production, and HFS were intermediate for the one-to-three year WDL members, and higher among the greater-than-three year members. Enhanced well-being of the greater-than-three year members was suggested by improved household characteristics (e.g. accessible water, latrine, floor construction), and may result from dairy income, although identification of causal relationships is limited by the cross-sectional approach.

Higher odds of HFS was associated with milk production however, average milk production was low (6.5 kg/cow/day). HFS was also significantly associated with women's group affiliation, greater-than-primary education, smaller household size, and consumer asset holdings.

WDL member women had higher milk and energy intakes, dietary diversity, and prevalence of overweight-status compared to non-member women. Longer membership duration was associated positively with milk-source nutrient intakes and percent energy from animal source foods (%ASF). Dietary diversity was positively associated with women's group membership and not with milk productivity or HFS. Diet quality measures, although better for WDL members, demonstrated micronutrient deficient diets.

Nutrition education may help address inadequate micronutrients intakes for members and non-member women as demonstrated by a high proportion of intervention-group women that adopted strategies to increase iron and zinc bioavailability. Intervention results for dietary diversity and intakes of vitamins A and C were dependent on WDL membership status. Greater dietary diversity was found for intervention group women that were WDL members. In contrast, higher intakes of

vitamin A and C were found for intervention group women that were not WDL members.

Overall, WDL members had strengthened livelihood measures particularly after 3 years. The intermediate status of the 1-3 years of members may be significant in setting realistic measurable development project goals. Findings provide evidence of the need to improve diet quality.

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List of Abbreviations

AI	Adequate intake
ANOVA	Analysis of variance
ASF	Animal source foods
%ASF	Percentage of dietary energy from animal-source foods
AVC	Atlantic Veterinary College, University of Prince Edward Island
BMI	Body-Mass index
β	Linear regression coefficient
CBS	Central Bureau of Statistics, Kenya
CHO	Carbohydrate
CIDA	Canadian International Development Agency
DD	Dietary diversity
DGLV	Dark green leafy vegetables
EAR	Estimated Average Requirement
FAO	Food and Agricuture Organization of the United Nations
FHF	Farmers Helping Farmers
HFIA	Household Food Insecurity (Access)
HFS	Household food security
IFAD	International Fund for Agricultural Development
IQR	Interquartile range
Kcal	Kilocalories
kJ	Kilojoules
KNBS	Kenyan National Bureau of Statistics
Ksh	Kenyan Shilling
MAR	Mean adequacy ratio
NAR	Nutrient adequacy ratio
NGO	Non-government organization
OF	Orange flesh fruit and vegetables
OR	Odds ratio
PII	Prevalence of inadequate intake
RE	Retinol Equivalent
RNI	Recommended nutrient intake
UNICEF	United Nations International Childrens Fund
UPEI	University of Prince Edward Island, Canada
USDA	United States Department of Agriculture
WDL	Wakulima Dairy Ltd.
Wfood2	World Food Dietary Assessment System Version 2.0
WHO	World Health Organization

CHAPTER 1 General introduction

Food and nutrition security are important as underlying factors in each individual's food intake and health, in their physical and cognitive capacities, and in a nation's capacity for economic and social growth and development. Enhancing agricultural productivity of smallholder farmer, through strengthening the capacities of farmers and rural agro-industries, is one strategy to address food and nutrition security.

Dairy farming is a livelihood option for some smallholder farmers in the central Kenyan highlands. Wakulima Dairy Ltd. (WDL) is a rural community-based organization that was established in 1992 and regularly accepts new members. WDL provides smallholder dairy farmers with markets for their surplus milk, regular milk payments, training, and other supports, in partnership with Farmers Helping Farmers and the Atlantic Veterinary College. Women are responsible for dairying on these smallholder farms, and efforts have been made to target training toward women and to ensure that women retain the income from milk sales.

A detailed scientific evaluation of the livelihoods and food and nutrition security of these farmers has not been conducted. There are few reports in the literature that examined food and nutrition security in such initiatives, nor examined associations among livelihood assets and food and nutrition security and duration of membership in a community-based dairy group. As well, few studies have examined the effect of nutrition education intervention on diet quality for dairy farm women.

The objectives of this thesis research were: 1) to identify associations among sustainable livelihood measures and duration of Wakulima Dairy Ltd. (WDL) membership in Kenya; 2) to identify determinants of household food security and women's nutrition security; 3) to determine effects of a nutrition education intervention on nutrition knowledge and practices; and 4) to explore factors influencing food choices to help explain intervention results.

The overall hypotheses of this research were: 1) that membership, and duration of membership, in the Wakulima Dairy Ltd. (WDL) were positively associated with sustainable livelihood assets and outcomes for smallholder Kenyan farm households; and 2) that the effects of nutrition education on women's nutrition knowledge and practices and women and children's diet quality were dependent on WDL membership duration.

The thesis begins with a review of literature, a description of the research setting, and the rationale for the research. Findings are presented in research-paper format. Objective 1 is addressed in Chapters 2 and 3 with descriptive and membership duration analyses of the cross-sectional survey data. Objective 2 is addressed through multivariable modeling in Chapter 4. Objectives 3 and 4 are addressed in Chapter 5 with results of a controlled trial investigating effects of nutrition education on diet quality, and survey data describing nutrition knowledge, practices and attitudes. The thesis concludes with a final chapter reviewing main findings and linking results among the objectives and providing direction for future research.

1.1 Literature review introduction

This review begins with an examination of the literature on poverty and the Sustainable Livelihoods (SL) Framework. Food and nutrition security and methods for their measurement are summarized next, followed by a section on agriculture-based approaches to enhancing sustainable livelihoods. This is followed by a discussion of approaches to poverty reduction and enhancing food and nutrition security through smallholder dairy farm intensification. Nutrition interventions are reviewed with an emphasis on food based strategies to enhance micronutrient intakes. Kenyan socioeconomic and living conditions of rural dwellers are presented, including an overview of food and nutrition security concerns of women and children. The chapter concludes with an introduction to the Wakulima Dairy Group, rationale for the research, and a description of subsequent chapters in the thesis.

1.2 Poverty and sustainable livelihoods

The majority of the world's poor in developing countries live in rural areas and many depend on small land areas (smallholder farmers) for food and income (IFAD, 2011). Smallholder farmers are challenged with limited agricultural resources (FAO, 2006) and typically engage in many different activities, rather than just one or two, to make a living. For example, "staples producers" were described by one group of authors as farming less than 2 acres of land, mainly as annual food crops (on 90% of their land), with a small portion of land devoted to perennial forage or cash crops, having livestock including higher milk producing cross-bred and dairy-cattle (versus indigenous cattle), and undertaking skilled off-farm work (Brown, Stephens, Ouma, Murithi, & Barrett, 2006). Among these farming households, a range of desired outcomes (e.g. food security, income, social status) and factors (e.g. access to resources, gender, culture) determine how and why decisions are made, how risk is spread, and how limited resources are balanced among competing needs in order to subsist in the short- and long-term (Maxwell et al., 1999). One way of understanding how these desired outcomes (e.g. improved food security, increased income) and resources (livelihood assets) interact is by using the Sustainable Livelihoods (SL) framework (Department for International Development [DFID], 1999).

1.2.1 Sustainable livelihoods framework

The SL framework is a tool to help conceptualize and understand the interrelated issues, processes and structures affecting people's livelihoods (Figure1-1) (DFID, 1999). Central to the SL framework is the complement of available assets (human, physical, natural, financial and social) that may be utilized in the pursuit of livelihood activities to achieve desired outcomes. Development programs using the SL framework aim to strengthen and balance the assets mix in order to improve resilience and quality of life for individuals, households, and communities, and to address existing enabling structures or barriers to transforming assets into desired livelihood outcomes, including cultural and gender issues (Brown, et al., 2006; IFAD, 2011). Through strengthened livelihoods, and if people are able to reinvest in their assets, a virtuous circle for further strengthening livelihoods, is created (Karanja, et al., 2010). In general, a strong complement of human capital (health, skills, knowledge and ability) is required to make use of the other assets and to pursue different livelihood strategies. The extent to which individual household members are entitled or lay claim to livelihood assets is dependent on various factors including age, position in the household, and gender (Lemke, Yousefi, Eisermann, & Bellows, 2012). This recognition has influenced development programming toward the use of multi-sectorial teams and analyses that enhance the likelihood of identifying the multiple constraints to sustainable livelihoods that face households.

Sustainable livelihoods are recognized as key determinants of food and nutrition security (Frankenberger & McCaston, 1998). Examples in the literature of the use of the SL approach to improve food security include a participatory multi-sectorial urban agriculture initiative aimed at strengthening livelihood capacities (technical, financial, environmental, and social) of HIV/AIDS affected households (Karanja, et al., 2010). In that study, analyses found women's limited access and control over essential assets (land, extension services, credit, and income) and low education limited livelihood improvements. Similarly, improved access to education and other human capacity-building activities, land, stipends and income, and networking resulted from agricultural interventions targeted to female smallholder farmers in South Africa (Lemke et al, 2012). In another example, changing livelihoods in an Inuit community was a significant determinant of household food insecurity (Ford & Beaumier, 2010). A review of the effectiveness of agricultural interventions to improve nutrition or health outcomes found greater success for interventions that invested in four or five types of SL assets (Berti, Krasevec, & FitzGerald, 2004). With the majority of the world's rural poor in developing countries dependent on small farms for food and income, strengthened agricultural capacity is vital to improving SL, as discussed in the following sections.

1.2.2 Strengthening agricultural capacity for sustainable livelihoods

Enhancing agricultural productivity of smallholder farmers is one means of improving national food availability and household food security, and is recognized as a sustainable approach to poverty and hunger alleviation (FAO, 1996; FAO, 2003; Matshe, 2009). Even modest gains in output by very large numbers of small farmers could have major impacts toward reducing rural poverty and hunger (FAO, 2003). When small farmers have more money to spend, they tend to spend it locally, and as a result, the incomes of the rural population as a whole, including landless labourers who make up a large proportion of the hungry and poor in many countries, are boosted. For example, households in dairy development projects hired more farm labour in Ethiopian (Tangka, Ouma & Staal, 1999) and Coastal Kenyan communities (Nicholson, Thornton, & Muinga, 2004). The sustainable livelihoods of smallholder dairy farmers are the focus of this thesis research, and, in this context, improved income and food security are important outcomes which are described in more detail below.

1.2.2.1 Income

Across nations with average incomes below $10,000 (US) per year, income level has been strongly correlated with well-being and 'life satisfaction' (Camfield, & Ruta, 2007; Ruta, Camfield, & Donaldson, 2007; Veenhoven, 2000). More income is not difficult to understand; however, accurate measurement of income in developing countries is difficult due to the 'myriad' of transactions undertaken by self-employed people and a reluctance to reveal such information to strangers (Morris, Carletto, Hoddinott, & Christiaensen, 2000). As well, the value of current-income measures is limited due to short-term income fluctuations (Filmer & Pritchett, 2001). As a result, economic status in developing countries is often estimated using indicators based on asset ownership and housing characteristics rather than measures of current income or expenditures (Filmer & Pritchett, 2001; Morris et al., 2000). In general, income received infrequently and in larger amounts tends to be spent on non-food items more readily captured by examining assets (Jaleta, Gebremedhin & Hoekstra, 2009). In contrast, regular income is more likely used for day to day expenses, including food. Recent evidence points to regular dairy income being spent on physical assets, as some Tanzanian dairy farming households improved their homes after three to five years of dairying (Bayer & Kapunda, 2006).

Where it has been studied, women's income and increasing women's role in household decision-making processes are important for food and nutrition security (Kirithi & Tisdale, 2003). Women's income is more likely to be spent on food and other household needs (Tangka, Ouma, & Staal, 1999). Women's income in Peru, Jamacia and Mexico, for example, was used for food and related expenses (fuel, matches, soap, salt, sugar, oil, and cooking utensils) and children's schooling (Dewey, 1989; FAO, 2000). In contrast, men in central Kenya and several countries in Latin America and the Caribbean tended to retain more of their income for personal uses including drinking, smoking, and leisure, ahead of the nutrition of their children (Kirithi & Tisdale, 2003; Dewey, 1989; FAO, 2000). It is not uncommon for commercialization to lead to more male control of activities and incomes (Huss-Ashmore, 1996; Kristjanson et al., 2010), which is in keeping with a traditional African view of cash income being part of the male domain (Gladwin, Thomson, Peterson, & Anderson, 2001). In light of this evidence, gender was examined in the thesis research as an important consideration in livelihood outcomes.

1.2.2.2 Food security

Food security, first defined in terms of global food availability, has subsequently been conceptualized at the individual and household level. The World Food Summit (FAO, 1996) defined food security as the condition that exists "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". This definition embraces a hierarchy of food availability, access, and utilization, with each level being necessary, but not necessarily sufficient for attainment of the next level (Haddad, Kennedy & Sullivan, 1994).

Food access refers to the economic and physical access to food for households and individuals, and to food that is sufficient in quantity and quality, culturally appropriate, and nutritionally adequate (FAO, 1996). Access is related to, but not fully defined by, purchasing power and market factors. The informal food systems, such as "homegrown foods" for subsistence farmers in developing countries (Torheim et al., 2004) and "country foods" in Inuit tradition (Beaumier & Ford, 2010), may play a vital role in food access. Further, intra-household allocation of food quantity and quality is often unequal, favouring men and boys over girls and women in a range of settings, including sub-Saharan African (Coates, Webb, Houser, Rogers, & Wilde, 2010; Ford & Beaumier, 2010).

Insecurity of access to food exists when the household or individual has insufficient or inadequate quality and/or quantity of food to meet their needs or is at risk of losing sufficient access (Maxwell et al., 1999). It is generally thought that household food insecurity is first felt by women who are more likely to be responsible for growing or purchasing food, deciding what to cook each day, and for the preparation of food for the household (Webb et al., 2006). Household food insecurity was significantly associated with anxiety and depression for Tanzanian women (Hadley & Patil, 2006), and women will often reduce their food intake and experience hunger before others in the household (Coates et al., 2010). The experiences of household food insecurity were similar among 22 studies in 15 countries (Coates et al., 2006), and were characterized by the use of a progressive series of coping or adaptive strategies to avoid running out of food or children going hungry (Maxwell et al., 1999). Individuals facing resource constraints balance the competing needs of preservation of assets for future livelihood, income generation, food supplies, shelter, health and self-esteem, and may go hungry to a point in order to avoid going [more] hungry later (Frankenberger & McCaston, 1998; Maxwell et al., 1999). Measurement of household food security has been challenged to capture the subjective experiences of vulnerability and use of coping strategies, and research into valid measurement of food security is discussed in the next section.

1.2.2.2.1 Food security measurement

Various indicators of individual or household food security have been used, including adequacy of energy intake, weight loss, anthropometry (e.g. heights, weights), malnutrition, disposal of assets, or other measures reflecting poverty or income (Maxwell et al., 1999). These indirect measures are generally insensitive and can result in misclassification of households and individuals experiencing food insecurity with hunger (Radimer, Olson, & Campbell, 1990). Webb et al., (2006) concluded that indirect measures did not adequately capture experiences of food insecurity.

Stemming from research aimed at understanding people's experiences with food insecurity and hunger conducted in the 1990s, the Cornell-Radimer questionnaire was designed to capture the vulnerability and coping strategies and to identify and classify food insecure households (Kendall, Olson, & Frongillo, 1995). Four categories of food insecurity were defined ranging from when individuals or households experience uncertainty regarding their ability to access food, to the extreme of not having enough to eat and losing weight. Analysis of results from food insecurity surveys, including those using the Radimer-Cornell questionnaire, confirmed that affirmative response rates were relatively high for questions pertaining to less severe forms of food insecurity (e.g. anxiety or reduced food quality), and relatively low for items of greater food insecurity severity (reduced food quantity and hunger) and thus confirmed the validity of the questionnaire approach (Pérez-Escamilla & Segall-Corrêa, 2008; Frongillo, 1999). Analysis of these results were used to develop the Household Food Insecurity (Access) (HFIA) Scale for use in developing countries.

The HFIA is a rapid questionnaire-based method that can be used to assess the prevalence of food insecurity, and the impact of development projects aimed at reducing food insecurity (Frongillo, Rauschenbach, Olson, Kendall, & Colmenares, 1997; Frongillo, 1999; Webb et al., 2006). The questionnaire consists of nine experiential questions, with four frequency-of-experience categories, and methods to culturally adapt the questionnaire prior to use. Analysis of HFIA data was used to i) generate a continuous variable for the severity of household food insecurity; ii) categorize the severity of food insecurity; and iii) examine prevalence of anxiety over food access, the need to reduce food quality, and the need to reduce food quantity due to limited resources (Coates, Swindale, & Bilinsky, 2007). The questionnaire assumes that two families with the same HFIA score experience the same level of food insecurity, and that other households in similar or other settings respond similarly. Performance of the HFIA tool was assessed relative to dietary diversity and wealth indicators with data from Bangladesh (Coates, Webb & Houser, 2003), and validated for community, but not individual, household food insecurity assessment. Food security researchers have used the HFIA tool in Burkino Faso (Becquey et al., 2010), Uganda (Kadiyala & Rawat, 2012), and Kenya (Gewa, Onguttu and Yandell, 2011). In this latter study, a dichotomous food security variable was created by merging secure and mildly insecure to create a "food secure" category, and moderately and severely insecure to create a "food insecure" category. The use of a dichotomous food security variable was employed in this thesis research to examine determinants of household food security.

A systematic cross-cultural validation of the HFIA was conducted by examining data from nine studies across six countries (Deitchler, Ballard, Swindale & Coates, 2010). Internal validity was confirmed in some studies; however variability between studies was found and efforts to confirm cross-cultural validity of the HFIA tool were not successful. Further analysis of sub-sets of the HFIA questions for cross-cultural consistency led the authors to recommend the use of the three most severe questions from the HFIA scale (7. no food to eat in the household, 8. going to sleep at night hungry, and 9. going a whole day and night without eating), as a cross-culturally valid "Household Hunger Score" (Deitchler, et al., 2010).

The HFIA questionnaire was utilized in this thesis research in an effort to establish the level of food insecurity and compare food insecurity among the study groups, and was adapted to the local context, as recommended (Coates, Swindale & Bilinski, 2007).

The distinctions between food security and nutrition security are examined next.

1.2.2.3 Nutrition security

Food access security is considered necessary but not sufficient for nutrition security (Haddad, et al., 1994). Dietary intake and health status are immediate determinants of nutrition security (Figure 2) (Benson, 2004). Underlying these are food security status, quality of care (e.g. knowledge and access to education, ability to make choices, or personal preference), and resources for health (sanitation, hygiene, water quality, and health care practices) (Gibson, 2005a; Haddad et al., 1994; IFAD, 2011; UNICEF, 1997). For example, nutrition security (as indicated by height-for-age) of pre-school children of Coastal Kenyan dairy farming households was significantly associated with availability of household water from a pipe or well (Nicholson, Mwangi, Staal, & Thornton, 2003). Water from these sources may be better quality than water from other sources, leading to better health and growth, although such details were not explored.

Under-nutrition limits the health and productive capacity for millions of adults and children worldwide, and limits the potential for economic development of countries (Engle, 2007). Maternal and child under-nutrition is cited as the underlying cause of 3.5 million deaths annually, and 55% of all child deaths. Over half of children-under-five mortalities worldwide occur in sub-Saharan Africa (Allen, 2003; Black et al., 2008; Murray, Laakso, Shibuya, Hill, & Lopez, 2007; UNICEF, 2008). Under-nutrition in women can negatively affect women's ability to work, produce and prepare food, and care for children and leads to a heightened risks of adverse pregnancy outcomes including perinatal mortality, obstructed labour, premature delivery and low birth weight infants, and morbidity of the mother and her baby (Black et al., 2008; Gillespie & Johnston, 1998; Hyder et al., 2005). Stunting of children has its antecedents in pre-pregnancy and pregnancy, as undernourished women are less able to meet the increased nutrient demands of pregnancy and lactation while carrying out their normal daily tasks. This undernourishment leads to low maternal stores during lactation resulting in reduced breast-milk volume and quality, in particular the B vitamins, vitamin A and iodine levels (Neumann & Harrison, 1994). Low breast milk volume is one reason that very young infants may be fed [nutritionally inadequate] porridge (Hyder et al., 2005). In Kenya, mothers with low BMI (BMI< 18.5) had children with the highest stunting levels (45 percent), while children whose mothers were overweight/obese (BMI ≥ 25) had the lowest stunting levels (27 percent) (KNBS, 2010).

Chronic food insecurity was associated with adaptive changes to food intake, which were likely nutritionally inadequate, and were distinguished from strategies, such as reduced portion sizes, that are used to deal with immediate circumstances of insufficient food (Maxwell, 1996). This concern, that a food secure household may consume, and be satisfied with, a nutritionally inadequate diet was illustrated by the relatively low (54%) mean nutrient adequacy ratio (MAR with 100% indicating meeting requirements) averaged over 11 nutrients, among women classed as food secure in a poor urban area of Burkina Faso (Becquey & Martin-Prevel, 2010).

1.2.2.3.1 Dietary intake

In the 1940's, dietary deficiencies of protein or protein and energy were believed to be the primary cause of malnutrition and growth retardation in developing countries (Allen, 2003). In the 1980's a multi-country observational study, the Nutrition Collaborative Research Support Program, revealed that inadequate intake of micronutrients (vitamin and minerals), but not likely protein deficiencies, factored into the limited physical and cognitive growth and development of toddlers (18 – 30 month) and was associated with lethargy, poor attention and greater severity and risk of disease (Allen, 1993; Beaton, Calloway, & Murphy, 1992; Calloway, Murphy, Beaton, & Lein, 1993; Murphy, Beaton, & Calloway, 1992).

The typical diet in developing countries is characterized as low-quality and limited in terms of diversity, with more than 50% of the dietary energy coming from grains and/or starchy tubers. When high starch foods dominate, and diets lack diversity, particularly in relation to vegetables, fruit and animal source foods (ASF), the risk of multiple micronutrient deficiencies is high for women, infants, and school-age children (ages five through 14), even when energy and protein intakes are adequate (Arimond & Ruel, 2004; Arimond et al., 2010; Best, Neufingerl, van Geel, van den Briel, & Osendarp, 2010; Moursi et al., 2008). As well, the bioavailability of some nutrients in plant-based diets, the degree to which a nutrient is absorbed and used physiologically (O'Dell,1983), is limited due to the forms of the nutrient and the presence of chelating compounds (Gibson, 2005b). The majority of vitamin A is provided as pro-vitamin A carotenoids that need to be converted to utilizable vitamin A (retinol), as found in animal source. Pro-vitamin A absorption, bioconversion and bioavailability is also influenced by fat content of the meal and the food matrix, which makes it challenging to quantify vitamin A intakes from plant sources (Weber & Grune, 2012). Recent research recommended the use of conversion rates of 1:12 for β-carotene and 1:24 for β-cryptoxanthin and α-carotene which are one-half the previously used values (Food and Nutrition Board, 2005). Iron and zinc bioavailability is low in plant-based diets due to high intakes of chelating compounds (i.e. phytates and tannins) (Allen, 2003; Bwibo & Neumann, 2003; Demment, Young, & and Sensenig, 2003; Gibson, 2005b), combined with limited consumption of flesh foods, that contain a more bioavailable form of iron (heme-iron) and that enhance zinc absorption (Lonnerdal, 2000).

For women in developing countries, inadequate intakes of iron, zinc, calcium, vitamins A, B_6 and B_{12}, folate, niacin, thiamin, riboflavin and vitamin C are concerns (Allen, 2003; Arimond et al., 2010). Low intakes of iron, zinc, calcium and vitamins A, B_{12}, and riboflavin are also a concern for infants, toddlers and school children (Murphy, Calloway, & Beaton, 1995; Neumann et al., 2003; Siekmann et al., 2003; UNICEF, 2008; Kenya National Bureau of Statistics [KNBS] and ICF Macro., 2010). A correlation among the deficient micronutrients observed from the multi-country studies, suggested that increased consumption of animal source foods (ASF) may provide the needed micronutrients and displace fibre- and phytate-rich foods and improve growth and development among children (Allen, 1993; Beaton, Calloway, & Murphy, 1992; Calloway et al., 1993; Murphy, Beaton, & Calloway, 1992).

ASF provide multiple micronutrients, in particular zinc, iron, vitamin B_{12}, calcium, and pre-formed vitamin A (retinol), in abundant and readily available forms (Allen, 2003). A controlled trial with Kenyan school children providing snacks to increase energy, meat, or milk intakes found that higher intakes of pre-formed (animal source) vitamin A, heme iron, Vitamin B_{12}, and percentage of energy from animal source foods were positively associated with children's growth and cognitive development, whereas high intake of nutrients and antinutrients found largely in plant foods (fibre, phytates, phosphorus, magnesium, potassium and copper) were negatively associated with growth (Grillenberger et al., 2006; Neumann et al., 2003; Whaley et al., 2003). In addition, the prevalence of vitamin B_{12} deficiency (assessed via plasma) among Kenyan school children was significantly reduced by the inclusion of 200-250 ml of milk per day in their diets (Grillenberger et al., 2006; Murphy et al., 2003; Whaley et al., 2003).

Low ASF consumption is typical in recent assessments of the diets of Kenyan children nationally (Bwibo & Neumann, 2003). In the resource-poor settings in developing countries multiple barriers to increasing the intake of ASF exist, including economic, cultural or religious factors (Gibson & Hotz, 2001) despite the strong positive association between animal source food (ASF) intake, micronutrient status, and many human functions (Allen, 2003). Improving bioavailability of zinc and iron and increasing intake of pro-vitamin A from plant-source foods, given the limited-resource setting, were the strategies employed in the nutrition intervention portion of this thesis research. However, deficiencies in zinc and iron may not be fully addressed without higher ASF intakes (Gibson & Ferguson, 1998) and without addressing other determinants of nutrition security (Benson, 2004).

Although under-nutrition is the main concern in developing countries, increased income and urbanization have been associated with the transition to over-nutrition (Steyn, Nel, Parker, Ayah, & Mbithe, 2011). This transition is characterized by the consumption of a “Western diet” (high in saturated fat, sugar and refined foods, and low in fibre) and is associated with a higher prevalence of chronic diseases (Popkin, 2002).

Nutrition security, determined by dietary intake and health status, reflects utilization of the foods and nutrients consumed. To examine nutrient status requires the collection and analysis of biological samples (e.g. blood, hair), is more invasive and expensive, and is impacted by factors such as infections and co-morbidities. Adequate dietary intake is a necessary first step in nutrition security, and was the focus of assessments in this thesis research. In addition, indicators of both under- and over-nutrition were examined, given the focus on strengthening livelihoods, including increasing income. Instruments used for measurement of food intake are discussed in the next section.

1.2.2.3.2 Dietary intake measurement

Methods for measuring the food consumption of individuals are divided in two categories, quantitative daily consumption records and retrospective qualitative or semi-quantitative dietary history and food frequency questionnaires (Gibson, 2005a). Quantitative methods, including 24-hour recalls and weighed food records, are used when the estimated intake of specific nutrients or prevalence of inadequate intake is needed. A weighed food record has greater reproducibility but has limitations, including a high cost, high respondent burden, a need for literacy and numeracy (or a designated observer/recorder), along with the potential for the individual to alter their usual food pattern as a result of participation (Gibson, 2005a). For these reasons, single or multiple 24-hour food recalls are more commonly used, satisfying the need for individual food consumption data, and can yield accurate estimates of group mean and median nutrient intakes which can be compared across subgroups (Harrison, 2004). An interactive 24-hour recall, that included training the respondents before the recall and providing plates and other visual aids for portion size estimates, was developed and validated to reduce systematic and random error in assessing zinc intake in illiterate populations (Ferguson et al., 1995). To obtain reliable dietary information in rural Kenya, Kigutha (1997) recommended the use of local measures and being familiar with local eating habits. To determine children's food intakes using recall methods, both mothers and children should be included in the data collection interviews. The importance of also interviewing children was illustrated in a study where the omission of foods consumed out-of home, from the mothers' recall of children's intakes, contributed 13% and 19% of daily energy in the lean and harvest seasons, respectively (Gewa, Murphy, & Neumann, 2007). Gewa, Murphy and Neumann (2008) identified the need to improve the performance of the 24-hour recall method after finding that about 30% of food items found in a weighed food record, mainly fruit, added sugars, sweets and fats, were not reported by women in 24-hour diet recall records for themselves and their school children in rural Kenya.

To reduce systematic and random sources of error, the use of methods to enhance the ability of the respondent to remember food, portions, and ingredients and their desire to accurately report are needed. Methods that account for recipe variations by household, day, and season, for nutrient retention estimates for cooked and leftover foods, use food composition tables that account for cultivar and growing location, and methods to estimate nutrient bioavailability in mixed food meals are desirable, although not always possible. In addition, it is recommended to use multiple 24-hour recalls on all or a portion of the respondents to remove the effect of day-to-day variability and provide approximately unbiased estimates of a group's 'usual' intake (Harrison, 2004). Single intakes of good quality, with large samples, can provide accurate mean and median estimate and be used for comparisons among groups (Harrison, 2004), which was the method used in this thesis research.

Food intake data, with the use of food composition databases, are used to estimate nutrient intakes, adequacy of intakes, and to compute diet quality indices for individuals and for comparisons across groups (Harrison, 2004). Measures of diet quality used in the thesis research are described below.

1.2.2.3.3 Diet quality assessment

To assess the adequacy of nutrient intakes requires knowledge of the requirements, which are dependent on age, sex, and physiological status. The Recommended Nutrient Intake (RNI) is defined as the intake level sufficient to meet the daily nutrient requirements of the majority of individuals in a specific life-stage and gender group (WHO/FAO, 2004). RNI's are based on an estimated average nutrient requirement (EAR) plus two standard deviations above the mean, and are the nutrient intakes thought to provide adequate intake for 97.5% of the population. Nutrient requirements are normally distributed around the EAR, with the exception of iron that has a skewed distribution due to the requirements of menstruating women. For some nutrients, in particular calcium, there is limited understanding of individual requirements, and therefore “Adequate Intake” (AI) estimates are used.

The probability of adequate nutrient intake is computed using the joint distributions of the group’s usual nutrient intake, estimated from repeat recalls or all or part of the population, compared to their requirement distribution (National Research Council, 1986). Lack of confidence in the reliability of the distribution of requirements, often taken from a small sample of individuals, led to the use of a “cut-point” method to assess adequacy of intakes, with certain assumptions, but with relaxed need for the requirement distribution (Carriquiry, 1999). In this method, the proportion of the group with usual intakes below the EAR or AI provides an unbiased estimate of the prevalence of inadequate intake. Single 24-hour diet recalls were used in this thesis research, due to limited resources, as a result, the use of a ‘cut-point’ method will systematically overestimate the prevalence of inadequate intakes in the groups (Harrison, 2004).

The mean nutrient adequacy ratios (MAR) is the average of multiple nutrient adequacy ratios (NAR), usual nutrient intakes expressed as a proportion of the RNI or AI each limited to a maximum of 1.0. MAR values have been used to evaluate dietary adequacy in a variety of contexts, including urban African American and white adults in the United States (Raffensperger et al., 2010), adult men and women in rural Mali (Torheim et al., 2003), with the macro- and micronutrients examined varying with the study. Single 24-hour recall were used in this thesis research, as discussed above, and as a result, higher variances in the group's nutrient intakes have the potential to systematically underestimate MAR.

1.2.2.3.3.1 Bioavailability adjustments for iron and zinc

Algorithms have been developed to estimate iron and zinc bioavailability taking bioavailability enhancers (e.g ascorbic acid, flesh foods) and inhibitors (e.g. phytates and tannins) into account and are used in the analysis of data in the research presented (Bunch & Murphy, 1997). Soaking dry beans and discarding the soaking water before cooking reduces their phytate and tannin content (Fernandes, A. C., Waleska, N., & Da Costa Proença, R. D. (2010) and was promoted in this research as a means of increasing iron and zinc absorption. However, quantifying the effects of bean soaking on iron and zinc intakes may be limited by available phytates and tannins compositional data. Specifically, the phytate acid and tannin content of beans (Phaseolus vulgaris L.) varies with variety and growing conditions. Phytates ranged from 17.34 – 24.06 mg/g (dry matter) and tannins from 5.4 to 29 mg/g (dry matter) in three varieties of beans grown in East Africa (Bogale & Shimelis, 2009; Shimelis & Rakshit, 2007). Similar variability was found for three varieties of beans grown in Turkey where levels ranged from 1468 to 1549 mg/100 g of phytic acid and 57 to 72 mg/100g for tannins (Nergiz & Gökgöz, 2007).

Iron absorption may be enhanced by the inclusion of ascorbic acid ($\geq$50 mg) with meals, to counter the inhibitory effects of high intakes of (>100 mg) tannins (Siegenberg et al., 1991), and the inclusion of onion and carrot (Gautam, Platel, & Srinivasan, 2011) and organic acids, such as citric acid, in a meal (WHO/FAO, 2004). Other strategies to improve iron absorption include the separation of tea drinking and food intake, by 2 hours, to reduce the negative effect of tea tannins on iron bioavailability (Zijp, Korver, & Tijburg, 2000) and avoiding the intake of calcium-rich foods with a meal (Disler et al., 1975).

Research in this thesis, with a focus on food-based strategies to enhance intakes of iron, zinc, and vitamin A, assessed pre- and post-nutrition education intervention knowledge, practices, and intakes of foods and nutrients.

1.2.2.3.4 Diet quality indictors

Collecting and analyzing diet recalls is time consuming and costly. As a result, various diet quality indicators have been developed to provide for rapid, less costly methods to assess and characterize diets. No single gold standard indicator exists, and the choice of indicator varies depending on the purpose of the study. Indices used in industrialized countries tend to focus on dietary attributes associated with reduced risk of chronic disease (Arvaniti & Panagiotakos, 2008; Kant, 1996). Diets of resource constrained individuals in developing countries are typically high in carbohydrates, monotonous, and low in nutrient density (as described earlier) therefore, dietary quality indicators that identify low intake of key nutrients are most appropriate for the context of this thesis research.

Population-level dietary macronutrient distribution recommendations for a nutritionally balanced diet are 10-15% energy from protein, 55-75% from carbohydrates, 15-35% from fats, and to not exceed 10% energy from saturated fat (WHO, 2002). Percent energy from animal source foods (%ASF) is a recognized indicator of diet quality in developing countries although no specific cut-point has been established (Allen, 2003). Food variety or dietary diversity (DD) measures can provide a relatively simple means of dietary assessment and were positively correlated with adequacy of micronutrient intakes for women in resource-poor settings in rural Mozambique and Bangladesh, and urban or peri-urban populations in Mali, Burkino Faso, and the Philippines (Arimond et al., 2010). In these studies a stronger correlation between women's dietary diversity scores and mean probability of adequate intake of 11 micronutrients were found when minimum food consumption levels (>15 grams) were taken into account. However, the low mean probability of adequate intakes (<50%) in these studies limited the identification of a dietary diversity score that predicted adequate intakes. Consumption of a variety of at least 15 different foods (out of a maximum of 29 observed), or dietary diversity score of five (of nine), was needed to attain a satisfactory (0.75) MAR, based on intakes of energy, protein, fat, and 8 vitamins and minerals, for a random sample of children (ages 13-58 months) in urban Mali (Hatloy, Torheim, & Oshaug, 1988).

1.3 Dairy farming as a sustainable livelihood strategy

Dairy farming potentially offers smallholder farmers higher returns to land and labour than crops such as coffee or tea, along with the expectation of regular income (Delgado, 1999). Adoption of dairying as a livelihood strategy in Kenya was limited to households that could manage to acquire a first cow (Rangnekar & Thorpe, 2002, Brown, 2006). More affluent farmers, which in the small-scale sector means those with regular off-farm income, can accept higher levels of risk associated with adopting new technologies. For example, coastal Kenyan households with dairy cows also had larger landholdings and other general capital resources (Nicholson, et al., 2004).

Specific constraints facing dairy farmers include low reproductive rates, low milk production, and limited access to extension training and other animal health services (Bebe, 2003). Rural agro-industries are recognized as important links between farmers and the market (Moron, 2006) and may help farmers address the many challenges to entering 'semi-commercial' agriculture such as unreliable markets limiting food availability for the household, and limited transportation, agricultural support services, and market access for the surplus agricultural products (Bebe, 2003; Jaleta, Gebremedhin and Hoekstra, 2009). To expand the benefits of small-scale dairy production in rural areas, Reynolds Metz, & Kiptarus (1996) recommended initiatives to reduce risks, for example, of diseases to animals and forage supplies, of low productivity of cultivated forages with unreliable rainfall, and to optimizing breeding systems where artificial insemination is not economical, as opposed to a focus on maximizing production.

1.3.1 Strengthened dairy farm capacity: milk production and income

Strengthening the capacity of smallholder dairy farmers, through initiatives that included dairy-related technical training, improved dairy breeds, and better cattle management, resulted in increased milk production and/or farm income in Ethiopia, Kenya and India (Leroy & Frongillo, 2007; Kisusu, Mdoe, Turuka, & Mlambiti, 2000) and in Tanzania (Bayer & Kapunda, 2006; Lwelamira, Binamungu, & Njau, 2010). More than 60% of households in Coastal province, Kenya, involved in dairy enhancement initiatives had higher and more regular income compare to non-participating households (Nicholson, et al., 2004). Compared to non-dairying households in Ethiopian, household with enhanced dairying had 72% higher total monthly income, and average per-capita purchases of non-food items (clothing, health care and leisure), food, and farm inputs, were 1.9, 1.2, and 1.5 times higher, respectively (Ahmed, Jabbar, & Ehui, 2000). Ethiopian women in a dairy enhancement program had 7 times more dairy income compared to women in traditional dairying households and average per-capita food expenditures were 36% higher than those of traditional dairy farm women (Tangka, Emerson, & Jabbar, 2002). Kenyan women engaged in enhanced dairying reported increased food purchases, school fee payments, and book purchases relative to their previous expenditures (Mullins, Wahome, Tsangari, & Maarse, 1996). Some Tanzanian households with regular dairy income improved their homes after three to five years of enhanced dairy farming (Bayer & Kapunda, 2006).

A multi-factor analysis found that farmers' milk production in Kenya was responsive to the price for milk and the cost of good animal feeds, but that non-price, institutional and socio-economic factors, such as physical assets or infrastructure (roads and water access) and transforming structures (agricultural extension support for farmers and support for efficient production of good quality feeds) evoked a far greater production response (Kavoi, Hoag, & Pritchett, 2010). Similarly, the availability of milk marketing infrastructure and the need for dairy enhancement to be market-oriented and demand-driven were recommended for sustainable benefits of dairy intensification in Ethiopia (Ahmed, et al., 2003). Farmers were willing to accept some risk in adopting production systems to increase milk production when they were assured of a profitable market outlet, affirming the importance of marketing infrastructure investment. In contrast, higher milk production from a four-year project in Tunisia was not sustained after the project's completion and the authors speculated that this was due to a lack of human capacity in terms of developed leadership in the rural areas (Salem & Khemiri, 2008). Sustainability of dairy enhancement with a milk marketing cooperative in a village in India was limited because the women farmers experienced greater workloads and stress but without access to the income, and the cooperative was fraught with mismanagement (Sharma & Vanjani, 1993), reflecting insufficient human and social assets. In a Sustainable Livelihoods approach, the roles and influences of external forces, including governments and the private sector, and policies, culture, governance are addressed in planning development activities while strengthening livelihood assets (DFID, 1999).

1.3.2 Strengthened dairy farm capacity: food and nutrition security

The presence of animals on a farm does not necessarily indicate increased consumption of animal-source foods by the family (Demment et al., 2003). In addition, success of projects to increase livestock productivity does not necessarily directly translate into increased food consumption in the households of the producer (DeWalt, 1993). Randolph et al. (2007) argued that the effects of livestock ownership and enhanced production on livelihood outcomes (assets, health, and food security) were difficult to determine by logic. Livestock have many roles in the lives of the poor, from the provision of food, particularly milk and eggs, to financial and social assets. In commercial production, factors such as the control of production and income, the allocation of household labour, the maintenance of subsistence production, land tenure, and pricing policies for both cash crops and other foodstuffs are greater determinants of the nutritional impacts, compared to the choice of crop produced (DeWalt, 1993). Often households can acquire more calories and protein by selling milk and buying maize, and, for these reasons, milk sales may be rational from economic and satiety perspectives (Huss-Ashmore, 1992). As well, improved economic situation in a resource poor family in developing countries may result in the purchase of foods, for reasons of convenience, greater perceived social acceptability, or quality, that do not necessarily improve the family's nutrition security (Ruel, 2003). Nicholson, et al., (2003) concluded that the pathways between milk production and consumption contain nutritional "leakages".

Household level food and nutrition security benefits have been reported for Ethiopian (Ahmed et al., 2000; Tangka et al., 2002) and Kenyan dairy farmers adopting cross-bred cattle and intensified dairy farming practices (Nicholson, et al., 2004). Higher household income of dairy-producing households in coastal Kenya was associated with higher caloric intake (Huss-Ashmore & Curry, 1992). Ethiopian dairying households had higher average per-capita food expenditures and intakes of energy, fat, protein, carbohydrates, iron and retinol (Ahmed et al., 2000). For Tanzanian and Ethiopian smallholder dairy farm households, average per-capital caloric intake was positively associated with the number of crossbred cows, and negatively associated with household size (Bayer & Kapundu, 2006; Ahmed et al., 2000). Average per-capita caloric intake was also significantly associated with season, in Tanzania, and with the use of improved feed technologies, in Ethiopia.

Of 14 households interviewed in an evaluation of a coastal Kenyan dairy development project, more than 90% reported consuming "more" milk, and 64% reported that household members were ill less often (Nicholson, 1999). With dairy intensification, average per-capita milk consumption was higher in Western Kenya, (Walingo, 2009) and retinol intake (the animal source form of vitamin A most likely from milk) was higher in Ethiopia (Ahmed et al., 2000). Average per-capita milk use was significantly higher for households owning dairy-breed cows compared to households without cattle and or households with local cattle in Coastal and Central highlands of Kenya, but there was no significant difference in milk use between households without cattle and with local cattle breeds (Nicholson et al., 2003). The average household milk use (per-capita weekly average) was much higher (6.45 litres) in the Central Highlands compared to 0.97 litres per-capita per week in Coastal households (Nicholson et al., 2003). Average household milk use in Kenya was associated with farm size (number of dairy cattle) and ranged from 1.0L/adult consumer-unit (CU) on small subsistence farms to 1.6L/adult CU on medium farms and 2.2 L/adult CU for large commercial farms (Huss-Ashmore, 1996). In contrast, poor households in a village in India with a milk marketing cooperative reported lower milk consumption due to the pressure to sell the milk in order to repay loans (Sharma & Vanjani, 1993). Kenyan health officials cited the need for nutritional education programs to accompany dairy intensification to encourage households to consume more of the additional milk in order that dairy development achieve its full positive impact (Nicholson, et al., 2004). With the exception of milk consumption reportedly being higher for pre-school children of dairy groups members in Western Kenya compared to non-members (Walingo, 2009), few studies have reported on individual milk consumption.

Greater dietary diversity was related to higher household income for dairy-producing households in coastal Kenya (Huss-Ashmore & Curry, 1992). Women on larger commercial dairy farms consumed more milk, meat and eggs compared to women on small and medium Kenyan dairy farms in the Rift Valley (Huss-Ashmore, 1996). Greater frequency (per month) of milk and meat or fish consumption was also reported for Tanzanian small-scale dairy farmers compared to non-dairy farming households (Lwelamira et al., 2010).

Children's mean height-for-age but not weight-for-age was positively associated with cattle ownership (local or improved breed), in households in central highlands and coastal Kenya, which indicated improved nutrition in the long, but not necessarily short-term (Nicholson et al., 2003). In coastal Kenya, some degree of stunting in children under-five years old was found in 68% of households with improved breed cattle, compared with 72% of children in households with local-bred cattle and 79% of children in households without cattle (Nicholson, 1999). Ownership of a dairy cow(s) had a significant positive impact on height-for-age z-scores of children under-five in both central and coastal areas of Kenya and no negative impacts on child nutritional status were associated with dairy development, a potential concern with market-oriented production. However these researchers concluded that the increased dairy income was used for purchases other than food for children (Nicholson et al., 2003).

In a review of published literature on livestock interventions, Leroy & Frongillo (2007) concluded that there was insufficient evidence to answer whether the promotion of animal production is an effective means to alleviate under-nutrition.

There is a need for greater information on the intra-household allocation of sustainable livelihood assets (e.g. resources, income, and nutrients) to understand and enhance nutritional outcomes of dairy projects (Leroy & Frongillo, 2007; Nicholson et al., 2003). A sustainable livelihoods approach offers a framework for collaborative work and to meet the call for productive interactions between agricultural scientists and nutritionists to improve nutritional outcomes (Demment et al., 2003).

1.3.3 Gender and sustainable livelihood

Where it has been studied, women's income is more likely to be spent on food and other purchases that benefit the household compared to men's income (Tripp, 1982). As a result, the impacts of an improved economic situation in terms of food and nutrition security are dependent on the context, in particular, who does the work and who controls the income (DeWalt, 1993). Interventions with a market orientation can lead to increased men's control over the activities and income and there is strong evidence from Latin American and Caribbean countries and Kenya that men tend to spend money on leisure and personal activities, rather than food for the household in (Dewey, 1989; Kiriti & Tisdell, 2003; Tangka, Ouma, & and Staal, 1999; Huss-Ashmore, 1996; Kristjanson et al., 2010).

Women have been the dominant dairy operators in Kenya, milking, watering, feeding and caring for the animals regardless of who was the head of house (Tangka et al., 1999). Despite an increased workload, Kenyan women involved in smallholder dairy production reported being better off due to income increases and stability (Mullins et al., 1996). This may be reflective of rural Kenyan women earning cash income and having independent (42.9%) or joint (47.2%) control about how the income was spent (KNBS, 2010). More specifically, smallholder dairy farm women in Central Kenya reported independent (41%) or joint control (35%) of dairy income with market-oriented production (Tangka et al., 1999). In contrast, Ethiopian women were not generally responsible for cattle keeping and a market-oriented dairy project had little impact on women's workload or income (income increased 4 times) but increased men's income by 14 times (Tangka et al., 1999). A greater degree of commercialization, in larger Kenyan dairy farms, was associated with more male control of activities and incomes (Huss-Ashmore, 1996). Sharma & Vanjani (1993) were critical of market-oriented dairy development in rural Rajasthan that increased women's workload and stress without income or other benefits, and concluded that changes to cultural traditions and gender inequities were necessary for success in dairying to strengthen livelihoods of women in India.

There are concerns that dairy intensification may re-focus labour (primarily women's) and land on the livestock, reducing time for, and quality of, childcare, food farming and preparation, and feeding of young children (Randolph et al., 2007). However, there is a lack of evidence on the impacts of dairy intensification on women's income, time, and workload (Leroy & Frongillo, 2007).

1.4 Nutrition intervention strategies

Nutrition interventions can take many forms, and range from provincial or national programs to programs targeting individual or households. Recent evidence indicates that childhood nutritional status is determined at the household or even individual level (Fenn, Morris, & Frost, 2004). Consequently, geographically targeted nutrition programs may result in high levels of under-coverage and leakage, and compromise their cost-effectiveness and appropriateness (Berhe, 1997).

To combat micronutrient deficiencies the fortification of commonly consumed foods have been effective in some cases (e.g. iodized salt for goiter control), however identification of an appropriate vehicle for fortification remains a challenge in resource constrained settings. Delivery of micronutrient supplements remains an option for short term alleviation of specific deficiencies such as vitamin A, and to a lesser extent iron, but robust delivery infrastructure and obtaining secure, long term funding remains a challenge. In order to address multiple micronutrient deficiencies simultaneously in developing countries, food-based strategies have the potential to be more economically feasible, sustainable, and culturally acceptable (Demment, et al.,2003; Gibson & Hotz, 2001).

1.4.1 Food based strategies

Food-based strategies to combat multiple micronutrient deficiencies aim to increase the production and consumption of micronutrient dense foods and promote food consumption and preparation practices that enhance nutrient absorption (Gibson & Ferguson, 1998; Ruel, 2001). In Peru, iron and ASF intakes were increased for women and girls through a community kitchen intervention that promoted and facilitated the use of low cost organ meats (Creed-Kanashiro et al., 2003). A multidisciplinary intervention in Malawi that introduced new crop cultivars, food preparation and preservation technologies, and provided parents with nutrition education, resulted in significantly higher percent of dietary energy from ASF, improved intakes of heme iron and zinc, and significantly decreased anti-nutrient intakes (Yeudall, Gibson, Cullinan, & Mtimuni, 2005). Similarly, an Ethiopian dairy goat production project that included additional complementary agricultural activities, and numeracy, literacy and nutrition education for women was associated with increased average per-capita household consumption of calories, fat, protein, retinol and iron (Kassa, Ayalew, Habte, & and G/Meskel T., 2000). Improved nutrition outcomes were observed in agricultural development projects that included nutrition objectives and invested in more than three of the recognized five livelihood assets, in particular, education of women in nutrition (Berti, Krasevec & Fitzgerald, 2004).

1.5 Kenya

Kenya is a developing country of about 38 million people with roughly 80% living in rural areas and 53% of rural dwellers classified as 'poor' (KNBS, 2010). Land with high agricultural potential, representing approximately 20% of Kenya's landmass, is mainly located in the Central and Rift Valley provinces. A high proportion of rural women (51%) and men (52%) are engaged in agriculture (self-employed or otherwise), and most people (>55%) are in the three lower wealth quintiles for the country (KNBS, 2010). Agriculture in Kenya is recognized as a key sector for poverty reduction (Government of Kenya, 2009).

Kenyan subsistence farmers depend on bimodal rains, historically occurring in March to May and again in October to December. Rainfall is influenced by altitude and proximity to lakes or the ocean. Climate change is affecting rainfall in Kenya resulting in more frequent periods of drought and negative impacts on farm production and food security (USGS, 2010).

The average Kenyan household has 4.2 persons with rural households being larger on average than urban households (4.6 to 3.1 persons respectively). Few rural homes have electricity (only 8%). Most rural homes (70%) have earth, sand or dung floors while 30% have hard surface, such as cement or tile floors. Cooking is done in a separate building by 60% of rural households using wood (83%) or charcoal (11%). Nationally, 54% of rural households have improved (clean) sources of drinking water (e.g. piped) while the remainder (46%) obtain water from unsafe sources (e.g. surface wells, lakes, streams, and rivers). In rural households, adult women are six times more likely than adult men to fetch water. A lack of ready access to water, places a disproportionate burden on female members of the household, who carry water from distant sources, and can limit hygiene activities. Use of unsafe water can infect household members causing illness, diarrhea and infection (KNBS, 2010).

1.5.1 Food and nutrition security in Kenya

The national dietary energy supply in Kenya over the period 2006-2008, was estimated at 2030 kcal/capita/day, with a population average energy requirement of 2200 kcal/capita/day (FAO, 2010). The prevalence of undernourishment, estimated as the proportion of the total population whose dietary energy consumption is continuously below a minimum dietary energy requirement, was estimated to be 33% (FAO, 2010). The macronutrient distribution of available dietary energy (11% protein 3% of which was animal-source, 20% lipid and 68% carbohydrate), was comparable to WHO/FAO recommendations (WHO/FAO, 2002). In rural Kenya, 14% of women were underweight (BMI <18.5) and 37% of children under-five years old were stunted, while 15% were severely stunted, providing evidence of chronic malnutrition in these rural areas (KNBS 2010). Evidence for the transition from under to over-nutrition, also known as the nutrition transition (Popkin, 2002) in Kenya is reflected in the proportion of overweight and obese women (BMI$\geq$25) which was 20.1% in rural and 39.8 in urban areas (KNBS, 2010).

Multiple micronutrient deficiencies, particularly zinc, iron, vitamin A, and iodine are wide spread in Kenya (FAO, 2005; UNICEF, 2008). In a review of literature, low serum zinc (<65 µg/dL) was reported for approximately 50% of Kenyan children under-five years, and 50% of Kenyan men, women and children surveyed, resulting in a high risk of zinc deficiency for these groups in the general population (Drorbaugh & Neumann, 2009). A national survey of women and children, representative of the diversity of ecological and altitude-regions of Kenya, examined serum hemoglobin, zinc and retinol and clinical symptoms of deficiencies to establish prevalence of iron-deficiency anemia, and acute and moderate vitamin A and zinc deficiencies in mothers and their children (Kenya Ministry of Health, 1999). In rural Kenya, 43% of women of reproductive age suffered from iron-deficiency anaemia and 56% of women and almost 43% of children under-five years were iron deficient in another sample. Subclinical vitamin A deficiency was reported for 84% of preschool children and 76% of preschool children exhibited signs of vitamin A deficiency (1999 figures). Among rural Kenyan women with a child born in the last five years, 1.7% reported night blindness, a symptom of severe vitamin A deficiency (KNBS, 2010).

Legislation authorizing iodized salt in Kenya was passed in 1989 (Muture & Wainaina, 1994). Preliminary evidence suggested that the prevalence of goiter in three Districts of Kenya declined rapidly after the introduction of this legislation

(Kavishe, 1997). In the 2008 Demographic Health Survey, 98% of households reported consuming adequately iodized salt (15 ppm) (KNBS 2010). As a result, iodine was not addressed in the thesis nutrition intervention.

1.5.2 Smallholder dairy farmers in Kenya

Smallholder dairy farmers produce staple food crops (maize and beans), animal foods, and cash crops along with raising animals on small parcels of land, usually less than 2 hectares. Following independence in 1963 and the liberalization of milk marketing in 1971, the Kenyan government promoted more intensive market-oriented smallholder dairying. Dairying was considered a suitable agricultural activity for smallholders, potentially offering high returns to land and labour (Delgado, 1999), particularly with the demand for local (raw) and processed milk strong and expected to grow over the next 25 years (Thorpe, Muriuki, Omore, Owango, & Staal, 2000).

Most of Kenya's 3 million dairy cattle are held in small herds (1-2 animals), on the smallholder farms of Central and Rift Valley provinces (Thorpe et al., 2000). Recently an average herd size of 2.2 improved dairy or dairy-cross bred cows was reported for farm households in Central Kenya (Kijima, Yamano, & Baltenweck, 2010). Many dairy cattle are housed in zero-grazing units where feed, mainly napier grass (Pennisetum purpureum), is cut and carried to the cattle along with crop residues and purchased feed. Zero grazing is complementary to cropping as it allows manure to be collected and used to maintain soil fertility and enhance yields of napier grass and other crops (Lwelamira et al., 2010).

Constraints to Kenyan agriculture include limited application of recent agricultural research innovations, inadequate credit facilities, and limited extension services.

Dairy farmers face additional barriers including low milk production levels, low reproductive rates, poor health management practices and high feed input costs (Bebe, 2003; Government of Kenya, 2009). Limited access to available agricultural extension services, affects women in developing countries more than for men, due to time constraints, and cultural and literacy factors (Kristjanson et al., 2010).

1.6 Wakulima Dairy Ltd.

Wakulima Dairy Ltd. (WDL – formerly a Self-Help Dairy Group) was established in 1992. WDL is now comprised of approximately 6000 active smallholder farm households throughout the Mukerwe-ini Division, in the Kenyan highlands, and represents approximately 27% of the Division's population (estimated at 90,000 in 1999). WDL buys (and markets) raw milk from its members and provides a broad range of services on credit, including milk transportation, animal feed, veterinary services, school fees, and household food and supplies. WDL has gained the trust of the farmers through good overall governance with regular monthly farmer payment, and has assured stable and continued market access for its milk by being a committed supplier of high quality milk.

WDL has worked in partnership with Farmers Helping Farmers (FHF), a Canadian volunteer-based NGO, since 1996 along with faculty and students from the Atlantic Veterinary College, University of Prince Edward Island (AVC-UPEI), since 2004. Efforts of these partners have focused on strengthening the capacities of the dairy group and farmers to improve dairy production, farm income, food security and the well-being of the farmers and community. FHF provided capital equipment and infrastructure support to the dairy group, along with dairy farm training to farmers.

Four sequential projects, funded in part by the Canadian International Development Agency (CIDA), allowed incremental capacity-building to occur, with each project building on the foundations provided by previous project(s). Extension training for women and men farmers included information, demonstrations, and fact sheets provided by supported Kenyan staff and FHF volunteers. Training topics included growing feeds and making silage, feeding for healthy calves and for milk production, animal health and reproduction, mastitis control and milk hygiene.

Women farmers were the focus of training, although not to the exclusion of men. FHF and WDL development projects have included efforts to engage and support the women farmers and keep the dairy income in their control.

A survey of 30 WDL farmers found increased reproductive rates and milk production between 2004 and 2006 (Vanleeuwen et al., 2012). Focus groups conducted by FHF with 24 WDL women farmers reported that women are retaining control of the income and experienced less domestic violence as a result (Vanleeuwen et al., 2012). Stemming from these results, further research was desired to evaluate the broader sustainable livelihood assets and outcomes, including food and nutrition security, with duration of WDL membership.

1.7 Rationale for research

It is anticipated that efforts to strengthen dairying capacity for WDL farmers would improve the income and quality of life of the member households. However, a scientifically rigorous evaluation of the impact of the development efforts of FHF with AVC on the sustainable livelihoods (including food and nutrition security outcomes), of WDL members has not been conducted. Such an evaluation is important in light of the complex role of animal ownership suggested by Randolph et al. (2007), and results of a review by Leroy & Frongillo (2007) which found that available evidence was insufficient to answer whether the promotion of animal production was effective in alleviating under-nutrition. In addition, it was noted anecdotally by members of FHF following visits to Kenya that some dairy farmers do not give their children milk to drink, preferring to sell the milk for financial reasons. It is worth discovering whether there is a lack of awareness among farmers of the short- and long-term benefits of milk, and a balanced diet in general, for their children. Examining farmers within short- and long-term WDL membership duration groups, and with a control group of non-member farmers, would improve the understanding of benefits of duration of dairy group membership on sustainable livelihood assets and outcomes. This improved understanding should help guide development projects and target funding to programs with expected sustainable impacts. Family nutrition education has not been offered to members of WDL in the past; therefore, it is unknown if such education could enhance any benefits of WDL membership on dietary quality. Family nutrition education, integrated with agricultural development projects, has previously been shown to improve family diet quality however no literature were found that examined the impact of nutrition education in conjunction with livestock development projects and the possible interactive effects of the two efforts on nutrition security. This information would potentially be useful to guide appropriateness and timing of nutrition education for households with and without agricultural capacity building interventions.

1.8 Thesis objectives

The overall goals were i) To describe SL assets and outcomes, including food security and diet quality for dairy group members and non-members; ii) to examine associations among SL assets and outcomes and membership status and duration; iii) to determine if nutritional seminars impact diet quality and whether seminar attendance and WDL membership duration interact to impact diet quality; and iv) to understand cultural attitudes toward food and diet and their influence on food choices and diet.

The objectives of **Chapter 2** were to i) describe family, farm and homestead characteristics and livelihood outcomes (income and food security) with WDL membership duration and ii) identify significant associations among dairy group membership duration, and family, farm and homestead characteristics, and livelihood outcomes.

The objectives of **Chapter 3** were to i) describe nutrition security (diet quality) of women and school age children with membership duration and ii) identify significant associations among dairy group membership duration and diet quality indices.

The objectives of **Chapter 4** were to identify multiple, possibly inter-related, significant determinants of (1) food security status and (2) nutrition security (diet quality) among dairy group membership duration and household and farm characteristics, including food security status as a possible determinant of nutrition security.

The objectives of **Chapter 5** were to determine the effects of a nutrition workshop on nutrition knowledge and diet quality and if the effects were modified by an interaction with WDL membership status or duration.

The final chapter, **Chapter 6**, summarized the methods and results from each of the five research chapters, how findings from each chapter related to each other, and suggestions for further work.

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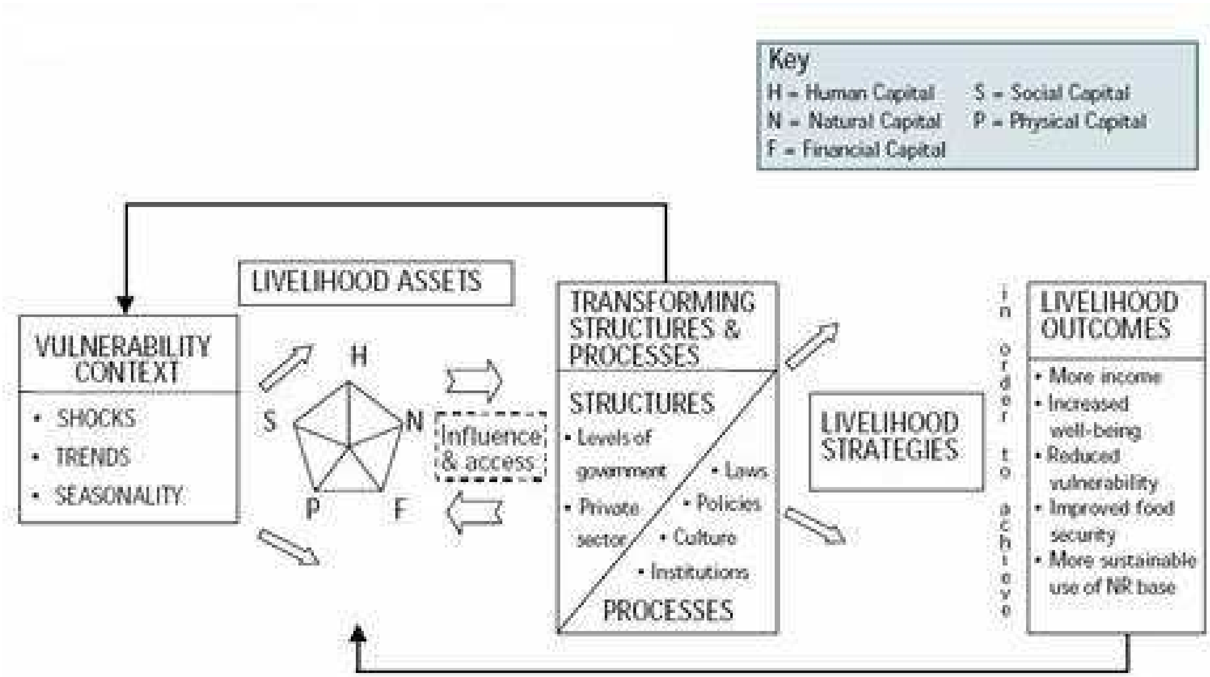

Figure 1-1. Sustainable Livelihoods Framework (DFID, 1999)

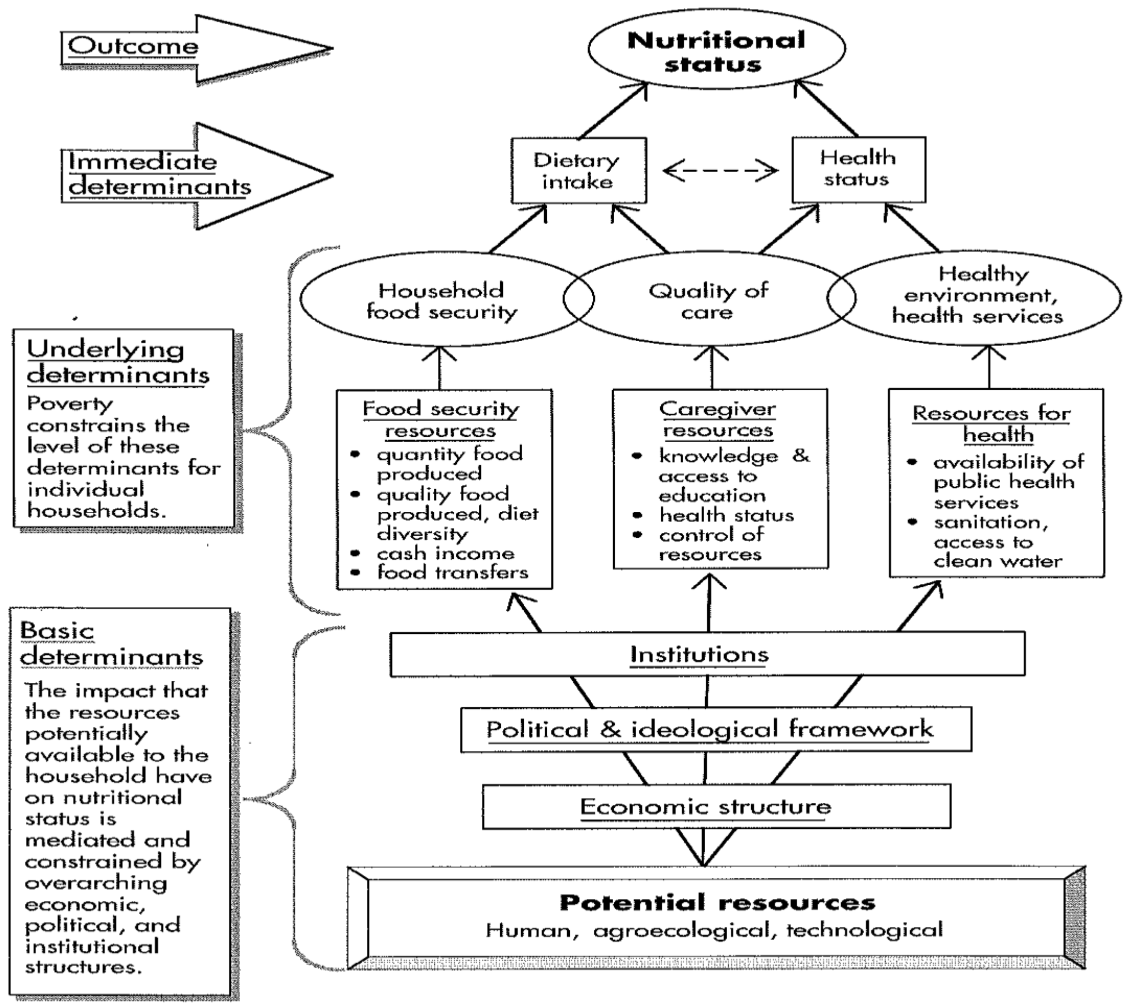

Figure 1-2. UNICEF conceptual framework of the determinants of nutrition security (adapted by Benson, 2004)

2 CHAPTER 2. Association between duration of community-based group membership and sustainable livelihoods for Kenyan women dairy farmers[1]

2.1 Abstract

Kenyan community leaders called for strengthened sustainable livelihoods for farmers and in 1992 formed a self-help dairy group that was reorganized in 2009 to form the Wakulima Dairy Ltd. (WDL). At WDL, members sell surplus milk to the dairy and, through nongovernmental organization (NGO) partnerships, receive training to enhance dairy farm productivity. As a result, higher milk production has been reported; however, data are lacking on sustainability and livelihood outcomes of dairy training for women farmers. To inform future projects and interventions, our study objectives were to determine the relationships between dairy group membership and duration of membership, sustainable livelihood assets, household income, and food security. We thus conducted a cross-sectional survey of 88 WDL members (among four membership duration groups) and 23 non-member farmers. Milk production and herd size were higher for greater-than-three-year members compared to non-members and one-to-three-year members. The proportion of households with an income from dairy of greater than 5,000 ksh/month (ranging from 0 to 40 percent), food secure status (ranging from 4 to 30 percent), and number of improved household characteristics (ranging from 1.7 to 3.3), were positively associated with longer membership duration. While the cross-sectional design does not allow attribution of

[1] Colleen Walton, John VanLeeuwen, Fiona Yeudall, and Jennifer Taylor Association between duration of community-based group membership and sustainable livelihoods for Kenyan women dairy farmers. Journal of Agriculture, Food Systems, and Community Development. 2012. Advanced online publication doi:10.5304/jafscd.2012.031.002

causality, results suggested that WDL membership strengthened the livelihood assets of women farmers, particularly after three years, and that positive outcomes were sustained with longer membership duration. Anecdotally, women indicated that WDL's role in women's control of dairy income, regular payments, and food and services on credit, were important. WDL is a model to strengthen sustainable livelihoods through relevant gendered training, supports, and market access for agricultural products. Research to understand the optimal asset mix to benefit from dairy groups as well as factors limiting per-cow milk production is needed to guide future interventions and enhance the role of dairy farming for sustainable livelihoods.

2.2 Introduction

Kenya is a developing country of approximately 40 million people, with roughly 80 percent living in rural areas. Nearly one-half the population is poor (unable to meet their daily nutritional requirements) and the majority of the poor live in rural areas (IFAD, 2011). The climate is varied, with 20 percent of the land being conducive to agriculture, particularly in the Central and Rift Valley provinces. These provinces are characterized by bimodal rains, typically occurring in October and March, which support agriculture. Smallholder farmers raise animals and grow staple foods (maize and beans) and other crops on small parcels of land, usually less than 5 acres (2 hectares). Most smallholder households in sub-Saharan Africa rely on agriculture for a significant portion of their income; however, productivity is typically low. Enhancing agricultural productivity of smallholder farmers is one strategy for reducing food insecurity and rural poverty (Matshe, 2009).

Dairy farming potentially offers smallholder farmers higher returns on land and labor than crops such as coffee or tea, as well as the expectation of regular income (Delgado, 1999). In Kenya, as with Tunisia and other countries, the demand for milk and milk products is strong and growing (Ben Salem & Khemeri, 2008; Thorpe, Muriuki, Omore, Owango, & Staal, 2000). Dairy-related technical training and improved livestock breeding have improved milk production and farm income in Kenya (Kisusu, 2000; Mullins, Wahome, Tsangari, & Maarse, 1996), Tanzania (Bayer & Kapunda, 2006), and Ethiopia (Ahmed, Jabbar, & Ehui, 2000). Hildebrand (2008) concluded, however, that measures to improve productivity, such as improved animal health and breeding, remain underexploited in relation to improving food security and rural livelihoods. Factors limiting higher livestock productivity, including time constraints and limited access to extension services, affect women more than men, and may limit the participation and efficiency of women in livestock production (Kristjanson et al., 2010; Yisehak, 2008). In Kenya, women are the dominant dairy operators and, despite an increased workload with dairying, reported being better off due to income increases and stability (Mullins et al., 1996; Tangka, Ouma, & Staal, 1999). In contrast, Ethiopian women generally were not responsible for cattle-keeping, and so intensification of dairying increased men's income with little impact on women's workload or income (Tangka, Emerson, & Jabbar, 2002). Dairy intensification in a village in India increased the workload and stress of the women but without increased income (Sharma & Vanjani, 1993). Women's control over income has been associated with purchases that provide a broader household benefit than purchases made by men. However, it is not uncommon for commercialization efforts to lead to more male control of activities and incomes (Huss-Ashmore, 1996; Kristjanson et al., 2010) in keeping with the traditional African view of cash income being part of the male domain (Gladwin, 2001).

Wakulima Dairy was established by a small group of community leaders in 1992, as a Self-Help Dairy Group, and governed by an elected board of representative farmers. Expansion of the activities and the number of members led to the incorporation of Wakulima Dairy Ltd. (WDL) in 2009. WDL remains governed by an elected board with a membership of about 6,000 independent member farmers throughout the Mukurwe-ini Division, Central province, Kenya. Its primary business is to buy raw milk from its members and transport and sell the milk to various markets. In addition, WDL broadly supports members by providing veterinary services, animal feeds, school fees, and staple household foods on credit. WDL has gained the trust of its member farmers through good overall governance and making monthly milk payments that provide members with a steady income. WDL has succeeded in providing farmers with stable markets for their milk by being a committed supplier of high-quality milk.

WDL has partnered with Farmers Helping Farmers (FHF), a Canadian NGO, since 1996, and with the Atlantic Veterinary College (AVC) since 2004, to strengthen the livelihoods of WDL's women farmers. Joint efforts were made to enhance dairy production through training and other supports and to retain women's control of dairy income. For three weeks each year, FHF volunteers and AVC faculty and students have assisted in practical training for farmers and efforts to improve the quality of animal health services. Four sequential projects with WDL were financed in part by the Canadian International Development Agency (CIDA). Kenyan staff, initially supported by project funds and then hired by WDL, continued the training throughout the year under the guidance of FHF and AVC. Women farmers were the focus of training, although not at the exclusion of men. Women were represented on the board of directors as a requirement of the FHF partnership.

Between 2004 and 2006, milk production and animal reproduction on WDL farms generally improved (VanLeeuwen et al., 2012). However, there is little published on broader sustainable livelihood (DFID, 2001) assets and outcome measures for women farmers belonging to community-based dairy organizations, nor on these measures associated with longer-term semi-commercial dairying as a livelihood strategy.

To inform future projects and interventions, our study objectives were to determine relationships between dairy group membership and duration of membership, sustainable livelihood assets and outcomes, including household income and food security.

2.3 Methods

2.3.1 Study site

The 6,000 WDL member households located throughout Mukurwe-ini Division represent approximately 29 percent of the division's population (estimated at 84,000 inhabitants in 2009) (Kenya National Bureau of Statistics, 2009). Milk is collected in trucks along four rural routes and from members within walking distance of the milk plant. There are non-member farmers living among the dairy group members.

2.3.2 Study design

A cross-sectional survey of 88 WDL member households, evenly distributed over four membership-duration groups (one- to three-, four- to six-, seven- to nine-, and 10 and more years), and a fifth group of 23 non-member households, was conducted in August 2009.

2.3.3 Sampling

A sample size of 20 households in each group was established to generate data with reasonable power, balanced with limited resources to conduct the research. Ten percent oversampling per group was included in case of spoiled or missing data. There was no central list with duration status or contact information for the 6,000 WDL member farmers and no reasonable and efficient manner to establish such a database to allow us to draw a stratified random sample. As a result, study participants in the four membership-duration groups were identified using chain referral sampling. This method is used to access “hard to reach” populations, such as those in developing countries (Heckathorn, 2002; Penrod et al., 2003). With chain referral, the study sample is created by referrals made among people (members) who know others possessing the “character of research interest” (membership-duration) (Biernacki & Waldorf, 1981). Eight WDL members were selected to initiate the referrals. These initiators represented a wide range of age, geographic distribution, and involvement within the dairy group. Each initiator referred farmer members who represented the four membership-duration groups. The research team contacted referred members to confirm membership duration. This procedure was repeated until sufficient numbers of members in each membership-duration group were identified. Referred WDL members were asked to identify non-members to generate a non-member list (n=50). The non-member participants (n=23) were randomly selected from this list. Limited resources to conduct the research precluded the creation of a list of eligible members and the use of random selection to establish the WDL study participants[2]. Directors and managers of WDL and teachers were excluded from the study to focus the research on households with farming as their primary livelihood strategy.

2.3.4 Questionnaire design

The survey included open-ended and multiple-choice questions on household demographics and environment, farm characteristics, income, and household food security. Household environment questions, which examined housing (e.g.,

[2] This statement was added after publication of the research article to address thesis reviewer comments

construction, repair, size), facilities (e.g., fuel, water, sanitation), and consumer assets (e.g., bicycle, radio), were modified from the Kenyan National Household Demographic and Health Survey (Central Bureau of Statistics [Kenya], Ministry of Health [Kenya], and ORC Macro, 2004). In order to develop a count index that represented household environment, housing and facilities were categorized as improved or not and a sum of improved home environment characteristics was computed for each household. For example, the number of buildings on the property and number of rooms in the main building was categorized as improved if the number was equal to or greater than the median number observed within the study. In addition, a vented cook house (i.e., with a chimney to exhaust wood smoke) and concrete or brick walls and floors were classified as improved. An improved latrine was one not shared with other families, as described in the Kenyan Demographic Survey (Kenyan National Bureau of Statistics [KNBS], 2010).

Primary and secondary household water sources were identified and included piped (to compound or neighbour), harvested rainwater, river or stream, public tap, and borehole (unprotected shallow well). The proportion of households using river or stream water as the primary or secondary source in both seasons was computed as an indicator of water access.

A measure of “household crowding” was computed from the number of daily household inhabitants divided by the number of rooms in the main building. Each household was categorized as above or below the median “crowding” for the study group.

Farm characteristics (e.g., acreage, herd size and age distribution, and milk production levels) were recorded. Monthly income (in categories) from milk, other farm product sales, and off-farm earned income were recorded. Milk income was based on the most recent full month of milk sales. Annual coffee income for 2008 was divided by 12 to estimate monthly coffee income. Midpoint values for each income stream were used to estimate household monthly income. Per-capita income was computed by dividing the monthly income estimate by the number of daily inhabitants. Women were asked who in the household controls the dairy income.

Household food insecurity (access) (HFIA) was measured using the validated "Household Food Insecurity Access Scale Version 3" (Coates, Swindale, & Bilinsky, 2007). Briefly, this method captures and quantifies predictable experiences and responses of household food insecurity with reference to the previous four weeks. Nine questions address anxiety and the need to reduce food quality and/or quantity due to food shortages. Questions progress from experiences of mild to severe household food insecurity. For each question the frequency-of-occurrence is assessed as never, rare (one to two times), sometimes (three to 10 times), or often (more than 10 times). HFIA responses were tabulated as per Coates et al., (2007) and summarized by membership duration group to describe (1) the prevalence of households categorized as food secure, mildly food insecure, moderately food insecure, and severely food insecure; (2) the prevalence of households experiencing the conditions of "anxiety," "reduced quality," and "reduced quantity" of food; and (3) the overall HFIA score (as a continuous variable ranging from zero to 27). A "Household Hunger Score" (HHS) was computed for each household using the three most severe HFIA questions based on the HFIA cross-cultural validation study (Deitchler, Ballard, Swindale, & Coates, 2010). The HFIA questions were culturally adapted to include local examples for prompts, as recommended (Coates et al., 2007).

Prior to use, the questionnaire was revised after review by WDL management and pre-testing on three households.

2.3.5 Survey administration

Family, farm, and demographic questions were posed to the husband and wife, depending on availability, or only the man or woman in single-parent situations. The person responsible for food preparation in the home, usually the woman, was interviewed alone (when possible) for household food insecurity and income control questions. The interview was conducted in person, using a translator as needed.

2.3.6 Data handling and analysis

Data were coded, manually entered using Microsoft Excel 2007 (Microsoft Office, Microsoft Corp. 2007), and checked for accuracy. The distribution of continuous variables was assessed visually and transformed (i.e., natural logarithm) to achieve a normal distribution. The normal distribution of transformed variables was confirmed using the Shapiro-Wilks test. Standard chi-square or Fisher's exact (categorical variables), ANOVA (normally distributed continuous data), and Kruskall-Wallis (not-normally distributed continuous data) tests were used to determine associations among the five membership groups (non-members through more-than-10-year members), and among members and non-members for demographic, production, and livelihood outcomes. Linear and logistic regression models were used to examine trends in outcome measures for an association with WDL membership duration[3]. Statistical analyses were conducted using Stata 10. Significance was assessed at $p \leq 0.05$.

Approval to conduct the study was obtained through FHF, WDL, and the University of Prince Edward Island Research Ethics Board prior to conducting the study. Signed consent was obtained from all participants after the nature of the study had been fully explained.

2.4 Results

2.4.1 Human and social capital

Men were the predominant heads-of-household (83 percent), while 10 percent of households were headed by widowed women. Overall, 83 percent of participants were married, which ranged from 65 percent in the seven- to nine-year group to 95 percent in the one- to three-year group. One participant was divorced and seven were single. Gender of household head and marital status were not associated with duration of membership.

As expected, the average age of WDL member mothers (range 21–73) and Husbands (range 24–78) increased with longer WDL membership duration, although the age of newer member groups were similar (Table 2-1). Comparing all-members to non-members, the average mothers' and husbands' ages were not different. Average household size (daily occupants) was lower for all-members (4.1) compared to non-members (5.1) and ranged from one to 10. Fewer non-member mothers and husbands had secondary education compared to all-members. A significantly greater proportion

[3] this sentence was added after publication of the journal article, for thesis coherence

of the seven- to nine-year group husbands had secondary education compared to other groups.

Fewer non-member mothers (48 percent) were affiliated with a Women's Self-Help Group (Women's group) compared with all-member mothers (70.5 percent). There was no difference in the women's group member proportions among the groups of WDL members. Overall, 84 percent of women reported belonging to a church, with no difference among membership groups.

2.4.2 Natural and physical capital

Almost all (99 percent) participants owned their home and land. The number of household buildings (mean two, a main building and separate kitchen; range one to five) and the number of rooms in the main building (mean three, range one to eight) were not associated with membership duration group. All main buildings had roofs of corrugated steel and were constructed with brick (45 percent) or wood plank/mud (55 percent) walls, with no membership group association. Duration of membership was positively associated with the proportion of households having a pit latrine at home, concrete or tile floors, and a vented cookhouse (Table 2-2). All households cooked with firewood or charcoal, and the majority used light from kerosene lamps. Solar light was used by five households and five others used electricity for lighting. Household crowding ranged from 0.25 to 4.5 persons per room in the main building, with a median of 1.3. More non-member households had higher-than-median crowding compared to all-members. The number of improved household characteristics (range zero to six) was positively associated with duration of membership (even after controlling for age[4]) specifically for households with seven or more years of WDL membership.

Fewer member households relied on river water in the dry season compared to non-members, and there was evidence of lower river-water reliance with longer membership duration (Table 2-3). More all-members used piped water in the dry season compared with non-members. Rainwater, stored in small buckets and large cisterns, was the primary household water source in the wet season. Throughout both seasons, the proportion of households using river water as a primary or secondary source was lower for all-members compared with non-members, and was lower with longer duration of membership.

Non-members owned fewer consumer assets than all-members (Table 2-4). Mobile phones and radios were the most predominant consumer asset. The proportion of all-member households with mobile phones was significantly higher than non-members'. Very few households owned a refrigerator, motorbike, or car/truck which reflected results for rural Kenya in the most recent national survey (KNBS, 2010).

Most households owned two acres (0.8 hectare) of land or less, with no difference among membership duration groups. More WDL members rented additional land than non-members (49 percent vs. 26 percent). Of these renters, most (88 percent) rented one acre (0.4 hectare) or less. The proportion of households dedicating their largest land area to napier grass (animal fodder) was higher with longer membership duration and there was a reverse trend for growing maize (figure 2-1). Members of the one- to three-year group did not follow the trend; many had their largest land area

[4] This analysis was conducted, and statement added, after publication to address thesis reviewer comments

dedicated to growing coffee. Significantly more all-members (40 percent) than non-members (9 percent) dedicated the largest land area to napier grass production. Significantly fewer all-members (24 percent) dedicated their largest land area to maize production non-members (61 percent). Some members (35 percent) and non-members (26 percent) dedicated their largest land area to coffee production.

2.4.3 Dairy farm characteristics

Women alone were responsible for dairy work on 51 percent of farms (range 31–70 percent across groups), and jointly with their husband on 45 percent of farms (range 13–70 percent across groups). Men alone were responsible for dairy work on 10–22 percent of farms across groups, and a hired hand was responsible for the dairy work in one household in the seven- to nine-year group and two in the 10 and more year group. No differences were observed among membership duration groups.

Herd size ranged from zero to six animals and the number of heifers from zero to four (Table 2-5). Non-members with cattle had smaller herds and fewer lactating cows than all-members. No differences were seen in the number of heifers among the membership groups. Daily milk production per farm ranged from 2.2 to 99.2 pounds (one to 45 kg), and per lactating cow ranged from 2.2 to 50.7 pounds (one to 23 kg). These production measures were higher for all-members compared with non-members and specifically for longer-term (greater than three-year) members. Short-term (one- to three-year) members had intermediate total and per-cow daily milk production. The proportion of milk sold ranged from zero to 96 percent, and was significantly higher for all-members compared with non-members, with no difference among WDL member groups. Milk retained for home use, from households with lactating cows, ranged from 0.3 to 3.3 lbs./capita (0.12 to 1.5kg/capita). One two-member household with four heifer calves retained 8.8 lbs. (4kg) of milk for household use. It was expected that some of the home-use milk was for feeding calves. On average all-members retained twice the per-capita milk compared with the non-members (n=4) with lactating cows. This difference was not statistically significant, but represents a potentially nutritionally significant trend depending on intra-household allocation.

2.4.4 Household income and income control

Household monthly income, from milk and coffee sales and casual and full-time jobs, ranged from zero to 27,000 Kenyan shillings (Ksh) (0-$385 Canadian dollars, Cdn). Per-capita total and non-dairy income was higher for all-members compared to non-members (Table 2-6). Income figures for non-members were of limited value, as many (n=13) non-members did not disclose coffee income. A greater proportion of households with more than three years of membership had high (more than 5000 Ksh/month) dairy income compared with one- to three-year members and non-members. Almost 80 percent of all-member women reported sole or joint control of dairy income. The two non-members reporting milk sales were not asked about who controlled dairy income because they did not sell milk to WDL.

2.4.5 Household food security

Among WDL members, 25 percent were food secure. A positive trend in the proportion of households classified as food secure by duration of membership was observed (Table 2-7). An opposite trend was observed for the proportion of severely food insecure households, which was lower as membership duration lengthened.

More all-members were categorized as food secure than non-members, particularly among members with more than three years of membership.

The proportion of households expressing anxiety over food security (the least severe form of food insecurity) was not different between groups (Table 2-8). Dairy group membership for more than three years was associated with fewer households that needed to reduce quality and quantity of foods consumed in the previous month compared with non-members. The proportion of households reporting reduced food quality or quantity among the four- to six-, seven- to nine-, and greater-than-10 year membership groups was not significantly different.

HFIA scores ranged from zero to 24, with a maximum possible score of 27 (figure 2). Longer-term (greater than three-year) dairy group members had better household food security (lower HFIA score) compared with non-members ($p < 0.10$). Non-member and one- to three-year member HFIA scores were not significantly different. HFIA scores for the three membership groups with more than three years of membership were also not significantly different, although the median HFIA score exhibited a linear trend ($p < 0.01$) toward lower food insecurity with longer membership duration. Household Hunger Scores were not associated with duration of membership.

2.5 Discussion

This study clearly demonstrated that belonging to the WDL dairy group in Kenya and the duration of membership were positively associated with women's livelihood assets and outcomes. Strengthened human, financial, and physical capital likely contributed to the increased resilience, capabilities and positive livelihood outcomes seen in WDL members. Rural agro-industries, such as WDL, are recognized as important links between farmers and the market (Moron, 2006) and may help address the many challenges to smallholder farmers entering "semi-commercial" agriculture, which include unreliable markets limiting food available for households to purchase, and limited transportation, agricultural support services, and market access for the surplus agricultural products (Bebe, 2003; Jaleta, Gebremedhin & Hoekstra, 2009).

2.5.1 Human and social capital

The age of the adults increased with membership duration, as expected. However, the mean age of all-members compared with non-members was not different, and therefore comparisons between these two groups, with similar time to learn, farm, and accumulate assets, are valid.

WDL member men and women had higher formal education levels and more member women participated in womens' groups. Higher education can increase human capital and positively impact capabilities, and may reflect higher overall livelihood assets that enable the investment in dairying; both scenarios making semi-commercial farming more achievable. Women's groups often provide microfinance to members, as well as learning opportunities, social security, and assistance in times of crisis, contributing to social assets (Cubbins, 1991). Members of women's groups may be better positioned to become WDL members and implement dairy production enhancements. However, attributing motivations and enabling factors for joining WDL was beyond the scope of this research.

WDL member women reported full or joint dairy income control in almost 80 percent of households and within the context of longer-term semi-commercial production. Tangka et al., (1999) found that 76 percent of Kenyan women in market-oriented smallholder dairying had some or full control of dairy income, although the traditional African view is that cash income is part of the male domain (Gladwin, 2001). Huss-Ashmore (1996) found that men controlled more of the dairy income in larger, more commercial farm households in Uasin Gishu District, Kenya. In Malawi and Uganda, men controlled high-revenue-generating commodities sold in formal markets (Njuki, Kaaira, Chamunorwa, & Chiuri, 2011). From this cross-sectional study we are not able to derive whether the efforts of the WDL-FHF partnership were a factor in the sustained income control. However, it is generally accepted that income in women's hands provides more household benefit than income in men's hands (Mullins, et al., 1996), which may help explain strengthened livelihood assets and more household food security observed for WDL member households.

2.5.2 Natural capital

Land access is very important to those who derive all or part of their livelihood from agricultural production. WDL members' ability to access additional rented land may be associated with higher income from higher milk production. As a result, member households may have greater capacity for sustainable livelihoods compared to non-members.

Land use differences between members and non-members (proportion of land used for napier grass as animal fodder versus maize production) are representative of the change typically seen when farmers transition from subsistence to semi-commercial agriculture (Jaleta, et al., 2009). The positive association of land use for napier grass and membership duration suggests that this land use shift occurred gradually and may represent greater commitment to dairy farming as a livelihood strategy over time. This difference also suggests more sustainable land use. Perennial napier grass has a broad leafy canopy and extensive root system that potentially reduces the rate of soil erosion compared with maize and coffee, which leave erodible soil exposed to water and wind. In addition, WDL members, who have relatively larger herds after the first three years of membership, have increased manure available from their own livestock, which, when used on crop and pasture plots, can increase crop yields and improve soil quality (Lwelamira, Binamungu, & and Njau, 2010).

The one- to three-year membership group was the exception to the observed land use trend. More farmers allotted their largest land area to coffee production. Higher world coffee prices and Kenyan government-initiated coffee market reforms initiated in 2003 (PKF Consulting Ltd. & International Research Network, 2005) may have impacted land use decisions by these farmers.

2.5.3 Physical capital

Housing characteristics and asset ownership, rather than measures of current welfare or poverty, are commonly used to measure economic trends in developing countries (Wamani, Tylleskør, Åstrøm, Tumwine, & Peterson, 2004). In general, regular income is used for food and other daily expenses, whereas income received infrequently and in large amounts tends to be spent on large durable items (Morris, Carletto, Hoddinott, & Christiaensen, 2000). Some Tanzanian households belonging to a well-managed community dairy group were able to improve their homes after three to five years of membership (Bayer & Kapunda, 2006). It is possible that improved household characteristics (latrine, concrete floor, vented cookhouse) and water access may have pre-existed WDL membership and enabled households to participate in intensified dairying. The differences observed with longer WDL membership duration suggest, however, that these improvements resulted from longer-term, stable dairy income. Although dairy income is received regularly, “building a house” was cited as one of the benefits of WDL membership (Walton, 2012). Improved sources and access (piped and sufficient rainwater) to water may similarly reflect the income benefits of longer WDL membership through investment in community water projects or the purchase of rainwater storage cisterns that are adequate to meet household needs during the wet season. The cross-sectional nature of the study does not, however, allow us to draw conclusions of causal relationships.

The differences observed in household characteristics for those with longer membership duration, suggest the potential for improved health and well-being and, consequently, strengthened human capital, through reduced risk of disease (due to having their own latrine, being less crowded, and having improved water sources) and respiratory problems and eye irritation (due to having a vented cookhouse) as well as, for women and children, a reduced burden of carrying river water.

2.5.4 Farm production and financial capital

WDL farmer training included best practices for breeding, raising, and maintaining healthy, productive animals. WDL also provided veterinary and artificial insemination services on credit to members. These activities are recognized capacity-building and supports needed to reduce reproductive losses and lead to sustained long-term benefits (Bebe, 2003;Walingo, 2006). Herd size, milk production (total and per cow), and dairy income were positively associated with WDL membership duration, particularly after three years of membership. Herd size for non-members reflected the median herd size of 1.3 animals reported for smallholders in the Kenyan highlands (Bebe, 2003). Increased milk production and incomes of smallholder farmers resulting from the use of cross-bred cows and better livestock management through farmer training, has been reported after two to four years in Ethiopia (Ahmed et al., 2000) and after three years in Kenya (Walingo, 2009). Sustained higher milk production with longer WDL membership may be attributed to the ability of WDL to market and pay for milk and to women retaining control of dairy income. Income control may enable women to fulfill their traditional role as food providers (Gladwin, 2001), while devoting their limited resources to dairying as a cash crop. Increased milk production in Tunisia due to similar interventions was not sustained beyond the intervention period, and this was attributed to the lack of common interest groups and leadership development (Ben Salem, 2008), although gender was not addressed in the intervention nor the evaluation. Non-members in our study had lower milk production that members, despite the potential to learn from WDL members in their communities. This may reflect the importance of social capital, belonging to a supportive group for training and implementation of enhanced agricultural practices.

In our study, per-cow milk production varied widely, which may be due to the low number of lactating cows in the study, and the fact that cow age, stage of lactation, and other influential factors were not taken into account. These factors limit interpretation of relationships between duration of WDL membership with milk production levels. The average per-cow milk production was not different for members after three years of membership and was low relative to the maximum observed. With generally low incomes and only 25 percent of households classified as food secure, there is a need to examine the role that higher milk production may play in addressing these issues.

The low number of lactating animals in non-member farms seemed to contrast with the relatively high number of heifers, as a young heifer can often indicate the presence of a lactating cow. This may be explained by non-members purchasing heifers or by low reproductive rates in the Kenyan highlands (Bebe, 2003), leading to older heifers and non-lactating cows. Other WDL intervention supports (e.g., a cow loan program) may explain the higher numbers of dairy animals for WDL members.

The seven- to nine-year member group had a larger proportion of households with high per-capita dairy and other income. A larger proportion of this group had some secondary education. As previously discussed, education can increase human capital and capabilities and make semi-commercial farming more achievable. The cross-sectional nature of the study, however, does not allow us to draw conclusions regarding causal relationships.

2.5.5 Household food security

The measurement of household food security, a complex phenomenon that includes psychological stress, coping mechanisms, and hunger, is evolving (Coates, et al., 2006). Previously reported smallholder dairy development projects used proxy measures of food security (farm productivity, income, milk and food consumption, and caloric intake) (Ahmed et al., 2000; Huss-Ashmore, 1996; Lwelamira et al., 2010; Nicholson, Thornton, & Muinga, 2004). Developments in the measurement of household food security led us to reveal the relationship between WDL membership and membership duration and (1) the severity of household food insecurity, and (2) the prevalence of households with anxiety about food access and with the need to reduce food quality and quantity due to limited resources.

August 2009, the time of the survey, was a lean period just prior to the maize harvest. In addition, there was a recent drought resulting in low maize yields; limited national food availability; and soaring world food prices (Wodon, 2010; World Vision, 2012). Anxiety about food access was widespread and not different between members and non-members, as expected when rains fail to come (Hadley & Patil, 2008). However, fewer member households, especially beyond three years of membership, reduced food quality and quantity, and consequently, fewer members were categorized as severely food insecure. The one- to three-year member households were intermediate in their degree of food insecurity and need for food quality and quantity reduction. This observation corresponds with their intermediate milk production and milk income, and further supports the argument that the benefits of WDL membership increase with longer duration. This group may have less access to staple food on credit from WDL compared to longer-term members due to lower milk sales to the dairy, further limiting household food security.

The HFIA score is considered a sensitive indicator of program impacts (Coates et al., 2006). In our study, a linear decline of median HFIA score (representing improving food security) with membership duration occurred despite members devoting more land to animal feed production, a recent drought, and high food prices. This situation indicates greater resilience and more sustainable livelihoods and likely reflects the benefits of long-term WDL membership. As well, women retaining control over dairy income is likely associated with these food security results. Dairy income was more often used to buy food on dairy farms where gender relations were addressed compared with farms where women accrued less of the income in proportion to their labor (Mullins et al., 1996). There was, however, a great deal of variation of the HFIA scores within the membership groups, likely reflecting the many intra-household variables and events beyond the scope of this research that can affect household food security.

Members retained twice the milk (per capita) compared to non-members (1.3 lbs./capita/d or 0.6 kg/capita/d vs. 0.7 lbs./capita/d or 0.3 kg/capita/d, respectively, $p=0.10$), even with greater commercialization as reflected by the proportion of milk sold by member households. The lack of statistical differences was due, in part, to low statistical power with a small number of non-members owning lactating cows ($n=4$). In contrast, in an Indian village where a milk-marketing cooperative operated, households consumed less milk compared to households in villages where cooperatives did not operate (Alderman, 1994). The per-capita milk retained by non-members (0.27 qt. (US)/capita/d or 0.26 L/capita/d) was similar to the milk consumption for Kenyan highland farm adults without cattle or with local cattle breeds (0.34 qt.(US)/capita/d, or 0.32 L/capita/d) (Nicholson et al., 2003). Higher average household milk consumption was found in dairy intensification programs in central Kenya (0.95 qt.(US) /capita/d or 0.9 L/capita/d) (Nicholson et al., 2003). In our study, the per-capita milk retained was less than that reported by Nicholson et al. (2003), but was more than the WDL farmer training that promoted “two cups” of milk daily for each household member (Walton, 2012).

WDL, a social asset and transformative structure, provided general support and specific efforts to strengthen human capital, and likely contributed to higher milk production, leading to both greater income and improved household food security. We hypothesize that these positive outcomes enabled members to strengthen their financial, physical, and natural assets that positively influenced their well-being, vulnerability, and sustainable land use. Most importantly, these positive results appeared to be sustained and some increased, with longer WDL membership duration. "Intermediate" was used to describe the dairy production and livelihood asset and outcome measurements for one- to three-year members. Other studies found higher milk production, average per-capita milk consumption, and income from milk sales among farmers involved in dairying for at least three years (Lwelamira et al., 2010; Walingo, 2009). We assert that this early period is needed to enhance women's capacity and confidence to use their limited resources for enhanced milk production. Most African women consciously plant and tend subsistence crops before most cash crops in order fulfill their traditional role as food providers (Gladwin, 2001). We believe the provision of staple food and other goods and services on credit from WDL are important supports for women to adopt semi-commercial dairying.

Limitations of the study include the cross-sectional design, which limits causal statements of the effect of dairy group membership (or duration) on specific outcomes. Members had higher levels of education (men and women) and social capital (women's group membership) that may have enabled them to become WDL members and to adopt enhanced dairying practices. More members had access to additional (rented) farmland, which may further positively impact their livelihood outcomes, and which may, or may not, result from dairy income. Another limitation was the use of chain referral sampling and its potential for selection bias, where an unbiased random stratified sample is preferred. To minimize the potential for this bias, chain referral sampling was carefully conducted and monitored (such as by using eight WDL member chain initiators with wide geographical distribution, and encouraging all initiators to refer households from all membership strata). Many characteristics of WDL and its partnerships are specific to this context and may limit generalizability of our results. Finally, comparability of food security assessment to other situations is limited, as the tool was not fully cross-culturally validated (Deitchler et al., 2010).

2.6 Conclusions

Our results support the statement that WDL membership status and duration are positively associated with income and food security and with strengthened livelihood assets that potentially impact additional outcomes (well-being, vulnerability, and more sustainable land use). We believe these results are strongly linked to the fact that women were the traditional dairy farmers and that efforts were made throughout the WDL-NGO partnership to train women farmers and keep dairy income in their control. This study illustrates a positive example for strengthening sustainable livelihoods of smallholder women dairy farmers; a strong and long-term NGO partnership with resources invested by all partners; a well-governed community-based organization; and gender mainstreaming through women being involved in decision-making, access to training, income control, and credit-based supports.

Movement to commercial production has the potential to paradoxically place a household at risk of food insecurity. Our results showed a positive association of per-capita income with WDL membership and of the prevalence of food secure households with membership duration. However, incomes were generally low and the majority of households were not food secure. Milk production (average per cow) was relatively low, even after the three-year adaptation period. There is a need to identify and address barriers for households to join dairy groups and factors limiting the rate of adaptation and the extent to which enhanced methods for milk production are adopted. Further, this knowledge will help guide interventions to increase income and household food security and to maximize the potential of dairy farming for sustainable livelihoods.

We recognize the limitation of the cross-sectional study design, which does not allow statements on direct causal effects of membership duration to be made. Further research using a longitudinal study design and a randomized sample would help fulfill the criteria for causality needed to confirm these hypothesized "impacts" of dairy group membership.

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Table 2-1. Household demographics, by dairy group membership duration[a]

	Non Members (n= 23)	Members 1–3 yrs (n= 23)	Members 4–6 yrs (n=22)	Members 7–9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
Mother's age mean (SE)	43.9 (3.0)a	35.1 (2.2)ab	34.4 (2.1)ab	43.3 (2.2)ab	52.9 (2.1)ac	41.5 (1.3)
Husband's age mean (SE)	52.3 (3.1)a	40.7 (2.4)b	38.8 (2.5)b	48.1. (3.8)ab	62.5 (3.7)ac	46.3 (1.8)
Household size[b] mean (SE)	5.1 (0.4)	4.0 (0.3)	4.3 (0.3)	4.3 (0.4)	3.8 (0.4)	4.1 (0.2)*
Mother's education attended						
% no formal and primary	90.9	81.2	69.6	50.0	63.6	66.7
% secondary	9.1a	18.2ab	30.4abc	50.0bc	36.4bc	33.3*
Husband's education attended						
% no formal and primary	81.8	70.0	63.7	25.0	80.0	62.4
% secondary and higher	18.2a	30.0a	36.4a	75.0b	20.0a	37.6*

[a] values having the same letter within each row are not significantly different ($p \leq 0.05$)

[b] Usual residents who eat at the home > 5 days per week

* All-member and non-member measures in the row are significantly different ($p \leq 0.05$)

Table 2-2. Household environment (% of households) and number of improved home characteristics by dairy group membership duration[a]

	Non Members (n=23)	Members 1-3 yrs (n=23)	Members 4-6 yrs (n=22)	Members 7-9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
Home construction						
Concrete/tile floor	4.4a	17.4ab	18.2ab	65.0c	52.2c	37.5*
Dirt floor	95.6	82.9	81.8	35.0	47.8	62.5
Facilities and utilities						
Pit latrine at home	65.2a	73.9ab	90.9bc	90.0bc	100.0c	88.6*
Pit latrine at neighbour	34.8	26.1	9.1	10.0	0.0	11.4
Vented cookhouse	8.7a	21.7ab	18.2ab	45.0b	39.1b	30.7*
Household crowding						
% with >1.3 people/room	78.3a	52.2ab	63.6ab	50.0ab	34.8b	50.0*
Number of improved characteristics						
mean (se)	1.7(0.2)a	2.1(0.2)a	2.2(0.3)a	3.3(0.3)b	3.3(0.3)b	2.7(0.1)*

[a] values having the same letter within each row are not significantly different ($p \leq 0.05$)

* All-members and non-member measures in the row are significantly different ($p \leq 0.05$)

Table 2-3. Primary water source in the dry and wet season by dairy group membership duration (% of households)[a]

Dry Season	Non Members (n=23)	Members 1-3 yrs (n=23)	Members 4-6 yrs (n=22)	Members 7-9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
River or stream	91.3a	69.6ab	50.0b	65.0b	52.2b	59.1*
Rainwater	0	0	4.6	10.0	4.4	4.6
Piped[b]	4.4a	21.7ab	27.3b	10.0ab	43.5b	26.1*
Borehole, spring, other	4.4	8.7	18.2	15.0	0	10.2
River as 1^0 or 2^0	91.3a	86.9ab	72.7ab	65.0b	69.6ab	73.9*
Wet Season						
River or stream	8.7	17.4	4.4	5.0	4.4	8.0
Rainwater	91.3	69.6	78.3	80.0	65.2	72.7
Piped[b]	0	13.0	13.0	10.0	30.4	17.0
Borehole, spring, other	0	0	4.4	5.0	0	2.3
River as 1^0 or 2^0	78.3a	47.8b	31.8b	35.0b	26.0b	35.2*

[a] values having the same letter within each row are not significantly different ($p \leq 0.05$)

[b] Water piped to compound, neighbor, and/or public tap

* All-members and non-member measures in the row are significantly different ($p \leq 0.05$)

Table 2-4. Consumer assets ownership, by dairy group membership duration (% of households)[a]

	Non Members (n=23)	Members 1–3 yrs (n=23)	Members 4–6 yrs (n=22)	Members 7–9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)	KNBS[c]
# of consumer assets[b]	1.7(0.2)a	2.5(0.2)ab	3.1(0.3)b	2.6(0.3)ab	2.3(0.2)ab	2.6(0.1)*	
Radio	74	91	91	80	77	85	71
Mobile phone	65	96	96	100	86	94*	53
TV	13	17	43	40	27	33	18
Bicycle	13	26	44	20	18	27	34
Solar energy	4	13	30	15	14	18	6

[a] Measurements in the same row followed by different letters are significantly different ($p \leq 0.05$)

[b] Mean number (SE) of the assets listed

[c] Results for rural Kenya from Kenyan Demographic Household Survey 2008 for context (KNBS, 2010)

* All-members and non-member measures in the row are significantly different ($p \leq 0.05$)

Table 2-5. Dairy herd and production characteristics, by dairy group membership duration[a]

	Non-members (n=23)	Members 1-3 yrs (n=23)	Members 4-6 yrs (n=22)	Members 7-9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
Herd size (all farms)	0.7 (0.2)	1.8 (0.2)	2.5 (0.2)	2.2 (0.3)	2.3 (0.3)	2.2 (0.1)*
Herd size[¶]	1.3 (0.1)a	1.8 (0.2)ab	2.5 (0.2)c	2.2 (0.3)bc	2.4 (0.3)bc	2.2 (0.1)*
# lactating cows[¶]	0.3 (0.1)	1.0 (0.1)	1.2 (0.2)	0.9 (0.2)	1.0 (0.2)	1.0 (0.1)*
# heifers[¶]	0.5 (0.1)	0.4 (0.2)	0.8 (0.1)	0.7 (0.2)	0.9 (0.2)	0.7 (0.1)
Kg milk produced/day[§]	3.1 (1.3)a	6.4 (1.0)ab	15.1(3.5)b	11.5	11.3 (1.8)b	10.3 (1.1)*
Kg milk produced/cow/day[§]	3.1 (1.3)a	5.5 (0.6)ab	7.7 (1.2)b	8.9 (1.0)b	8.6 (1.3)b	7.5 (0.5)*
% milk sold/day[§]	24.4(16.4)	66.5(5.4)	73.0(6.5)	76.7 (2.8)	75.2 (3.4)	72.3 (2.5)*
Kg home milk/capita/day[§‖]	0.3 (0.11)	0.5 (0.07)	0.6 (0.09)	0.6 (0.10)	0.6 (0.10)	0.6 (0.04)

[a] Data are expressed as mean (se) for consistency; measurements in the same row followed by different letters are significantly different ($p \leq 0.05$)
* All-member vs. non-member measures in the row are significantly different ($p \leq 0.05$)
[¶] Includes only farms with cattle (n=13 for non-members, n=22 for 10+ members)
[§] Milk production data from farms with lactating cows (n=4 for non-members; n=20, 15, 13, 17 for 1–3, 4–6, 7–9, 10+ years, respectively)
[‖] standard errors for kg home milk/capita/day were expanded to two decimal places in the thesis, for consistency

Table 2-6. Monthly income and income control by dairy group membership duration[a]

	Non Members (n[b])	Members 1–3 yrs (n=23)	Members 4–6 yrs (n=22)	Members 7–9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
Total per capita income (Ksh)[c]	278	1562	2500	2867	2094	2010*
	(58,729)	(1250,2770)	(1000,2667)	(1429,4500)	(1111,2850)	(1150,3055)
Non-dairy per capita income (Ksh)[c]	278a	847ab	833ab	1619b	570ab	917*
	(58,625)	(417,1750)	(200,2006)	(1060,3423)	(361,1458)	(416,1979)
Monthly dairy income						
% of farms earning 0 - 5000 Ksh	100	91	64	60	68	71*
% of farms earning > 5000 Ksh	0a	9ab	36c	40c	32bc	29
Dairy income control						
% of farms women sole or joint control	Na	78	77	80	78	79

70 Ksh = $1 Cdn (approximately, at the time of the study)

[a] values having the same letter within each row are not significantly different ($p \leq 0.05$)

[b] n=13 for non-members' total and non-dairy incomes; n=2 for non-members' dairy incomes

[c] Median per capita incomes with 25th and 75th percentiles

*Member and non-member measures in the row are significantly different ($p \leq 0.05$)

Table 2-7. Degree of household food insecurity by dairy group membership duration (% of households)[a]

	Non Members (n=23)	Members 1-3 yrs (n=23)	Members 4-6 yrs (n=22)	Members 7-9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
Secure	4.4a	17.4ab	27.3b	25.0ab	30.4b	25.0*
Mildly insecure	8.7	0	13.6	20.0	26.1	14.8
Moderately	26.1	47.8	22.7	30.0	17.4	29.6
Severely insecure	60.9a	34.8ab	36.4ab	25.0b	26.9b	30.7*

[a] values having the same letter within each row are not significantly different ($p \leq 0.05$)

* All-members and non-member measures in the row are significantly different ($p \leq 0.05$)

Table 2-8. Prevalence of food insecurity in three domains, by dairy group membership duration (% of households)[a]

Domain	Non Members (n= 23)	Members 1-3 yrs (n= 23)	Members 4-6 yrs (n=22)	Members 7-9 yrs (n=20)	Members 10+ yrs (n=23)	All Members (n=88)
Anxiety[b]	69.6a	56.5a	59.1a	60.0a	47.8a	55.7
Reduced quality[c]	95.6a	82.6ab	68.2b	70.0b	60.9b	70.4*
Reduced intake[d]	73.9a	56.5ab	40.9b	35.0b	34.8b	42.1*

[a] values having the same letter within each row are not significantly different ($p \leq 0.05$)

[b] Anxiety: feelings of uncertainty or anxiety over not enough food

[c] Reduced quality: not eating preferred foods, eating a limited variety of foods, or eating less preferred foods

[d] Reduced intake: smaller or fewer meals, no food stores in the home, going to sleep hungry, or not eating for a full day

* All-members and non-member measures in the row are significantly different ($p \leq 0.05$) (added for thesis consistency)

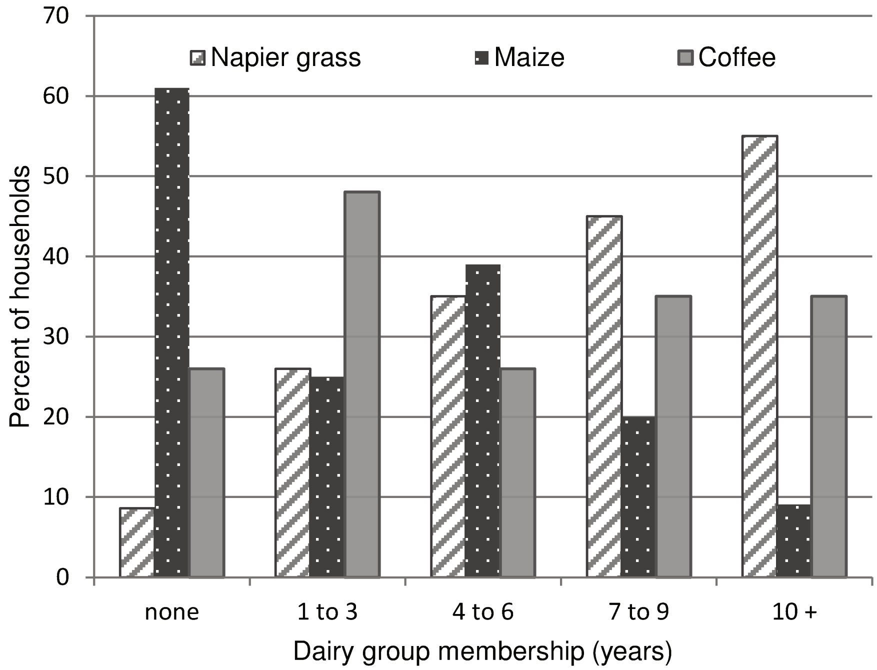
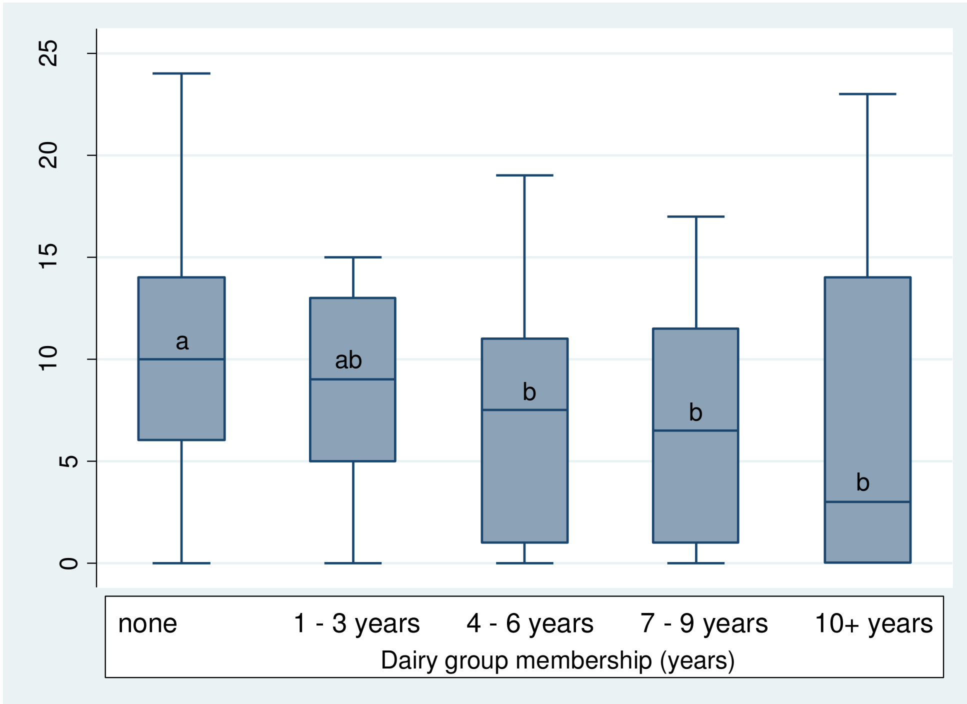


Figure 2-1. Crop occupying the largest farm area, by membership group



[a] Boxes with different letters have significantly different medians ($p \leq 0.05$)

Figure 2-2. Household food insecurity score (median, interquartile range, and range) by dairy group membership duration

3 Chapter 3 Diet quality with dairy group membership, membership duration, and non-membership for Kenyan farm women and children[5]

3.1 Abstract

Kenyan community leaders formed Wakulima dairy group in 1992 as a means of strengthening the livelihoods for farmers on small farms in central Kenya. Enhanced sustainable livelihood assets and food security have been reported for these farmers. Nutrition security, determined by dietary intake and health status, has food security as one of the underlying determinants. Nutrition security is important for individual in achieving their academic and productive capacities. The objective of this study was to examine associations among diet quality, dairy group membership, membership duration, and non-member status for women and school age children in rural Kenya. A cross-sectional survey, using chain referral sampling, was conducted and 24-hour dietary intakes collected for women and children of dairy group members (n=88), across membership duration groups (1-3, 4-6, 7-9 and 10+ years), and of non-members (n=23), living among members. Diet quality indices and prevalence of inadequate intake (PII) were estimated using the 'estimated average requirement' cut point method from single 24-hour recalls, using a Kenyan nutrient database. PII was compared among members and non-members and among membership duration groups.

Members had higher energy, percentage of energy from animal-source foods and dietary diversity. Member women and children, respectively, had lower PII for seven

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and three of 11 micronutrients. Reduced PII for milk-source micronutrients was associated with membership duration for women. Many member women (38%) had inadequate vitamin A intake, and 39% of member children had inadequate zinc intake. The member's PII was also high (>45%) for iron, calcium, and vitamin B12. A higher prevalence of being overweight among member women versus non-member women suggests nutrition transition effects of higher farm productivity. Dairy group membership was positively associated with adequate quantity and quality diets for women and children. Long-term membership was insufficient to address micronutrient deficiencies. Understanding and addressing barriers to better diet quality and strategies to mitigate negative nutrition transition effects are needed to optimize nutritional outcomes of dairy group membership.

3.2 Introduction

Maternal and child under-nutrition is the underlying cause of 3.5 million deaths annually, with over half of children under five mortalities occurring in sub-Saharan Africa (Black et al., 2008; Murray, Laakso, Shibuya, Hill, & Lopez, 2007). Widespread impacts of under-nutrition include under-nourished women giving birth to low weight infants, having reduced volume and quality of breast-milk, and with limited caring and working capacity (Black et al., 2008; FAO, 2006). The typical high starch plant-based diets usually lack sufficient diversity and this places women, infants, and school-age children (ages 5 through 14) at risk of multiple micronutrient deficiencies (Arimond & Ruel, 2004; Arimond et al., 2010; Best, Neufingerl, van Geel, van den Briel, & Osendarp, 2010). Inadequate intake of iron, zinc, calcium, and vitamins A, B12, and riboflavin are of concern for infants and young children (UNICEF, 2008; Siekman et al., 2003; Neuman et al., 2003) and recently, 11 micronutrients of concern for women in developing countries were identified (Wiesmann, Arimond, & Loechl, 2009). In Kenya, 35% of children under-five years are stunted (Kenya National Bureau of Statistics (KNBS) and ICF Macro., 2010) which is also associated with limited cognitive development (Grantham-McGregor et al., 2007). In addition, a high proportion of Kenyan children and non-pregnant women had mild to severe deficiencies of serum zinc (51 and 52%, respectively), hemoglobin (iron) (73 and 56%, respectively), and retinol (vitamin A) (84 and 51% respectively) (FAO, 2005; Kenya Ministry of Health, 1999).

The majority of the world's poor live in rural areas and many depend on small farms for food and income. In sub-Saharan Africa, including Kenya, smallholder farmers are challenged with limited agricultural resources (FAO, 2006). Improving the productivity of small farms is considered one of the best and most sustainable means for reducing hunger and nutrition in poor rural communities (Berti, Krasevec, & FitzGerald, 2004; FAO, 2003; Matshe, 2009).

Wakulima Dairy Ltd. (WDL), a community-based dairy group in Kenya, buys and sells member's raw milk, and provides them with regular payments and goods and services on credit. WDL member training to enhance dairy farm productivity has been conducted for over eight years through a partnership with Farmers Helping Farmers (FHF), a Canadian NGO, the Atlantic Veterinary College at the University of Prince Edward Island (UPEI), and the Canadian International Development Agency. Early in the training program, FHF volunteers were concerned that farmers may opt to sell all of their milk, to the detriment of household nutrition. The training program was then expanded to encourage households to provide children with two cups of milk each day for better school performance and health. This message, delivered by the WDL milk quality specialist, was accompanied by a two-page 'fact sheet' that reiterated the messages and included recipes to expand milk use.

Integrated participatory agriculture and nutrition interventions have demonstrated positive nutritional outcomes (Berti et al., 2004; Bezner Kerr, Berti, & Shumba, 2010), however, there is limited evidence of the effects of agricultural production interventions on individual's nutritional outcomes (Berti et al., 2004; Bhutta et al., 2008; Leroy & Frongillo, 2007). This is important for women and children who are often disadvantaged in household food distribution. Dairy farm enhancement initiatives reported higher milk production, household income, average-per-capita milk consumption, and intakes of energy, total fat, protein, retinol and iron (Ahmed, Jabbar, & Ehui, 2000; Huss-Ashmore, 1996; Kisusu, Mdoe, Turuka, & Mlambiti, 2000; Lwelamira, Binamungu, & Njau, 2010; Mullins, Wahome, Tsangari, & Maarse, 1996; Tangka, Ouma , Staal, 1999). Our previous results found WDL membership duration longer than three years was positively associated with higher milk production and that members had higher average per-capita milk compared to non-members (0.6 vs. 0.3 kg/person) (Walton, Taylor, Yeudall, & Vanleeuwen, 2012). Longer duration and intensity of involvement in an integrated agricultural and nutrition project had positive impacts on height and weight of children (under 3 years) in Malawi (Bezner Kerr et al., 2010) but no other reports detailing the duration impact of agricultural intervention, including enhanced dairy farming, on health and nutrition were identified.

The objectives of this study were to examine associations among dairy group membership, membership duration, and non-member status with diet quality indicators and prevalence of inadequate nutrient intake for women and school age children in rural Kenya.

3.3 Methods

3.3.1 Setting

WDL is located in Mukurweini division, Central province, Kenya. Farmer members live along four rural routes and around a central town. Non-member farmers live among the dairy group members throughout the division. The 6000 dairy group member households represent about 28% of the division’s population of 84,000 (Kenya National Bureau of Statistics, 2009).

3.3.2 Study design and sampling method

A cross-sectional survey of 88 WDL member households, evenly distributed over four membership-duration "study groups" (1-3, 4-6, 7-9 and 10+ years), and 23 non-member households, was conducted in August 2009. The sample size was established to generate data with reasonable power, balanced with limited resources, and included 10% additional participants to maintain numbers in case of spoiled surveys.

Study group members in the four duration groups were identified using chain referral sampling since there was no available list of members with duration status or contact information to use in selecting a stratified random sample (Biernacki & Waldorf, 1981; Penrod, Preston, Cain, & Starks, 2003). Eight WDL members were selected to initiate the referrals. These initiators represented a wide range of age, geographic distribution, and involvement within the dairy group. Each initiator referred farmer members that represented the four membership-duration groups. The research team contacted referred members to confirm membership duration. This procedure was repeated until sufficient numbers of members in each membership-duration group were identified. Referred WDL members were asked to identify non-members to generate a non-member list (n=50). The non-member participants (n=23) were randomly selected from this list. Directors and managers of WDL and teachers were excluded from the study in order to focus the research on households with farming as their primary livelihood strategy.

3.3.3 Survey and dietary assessments

The interview was conducted in person by two trained interviewers, including the first author, using translators, as needed. Demographic information was collected from the household adult(s) and women were interviewed for food preparation and consumption using a four-pass 24-hour recall (Gibson, 2005b). Dietary intake was recorded for the women and for a randomly selected child in households with at least one daily resident child (biological, grandchild or adopted) between 5 and 14 years. Children do not attend school in August, which was the time of the survey and, when available, children verified food intake reported by the mother and provided information on additional foods consumed. In two households, the husband was the main food preparer and was similarly interviewed, but only data for the child's food intake was analysed. Interviews were conducted to ensure each day of the week was evenly represented in the recalls for each membership group.

Women's weight was measured using a 'Salter-Speedo' dial mechanical scale (Model 148) (0.5 kg accuracy). Height was measured using a rigid measuring tape (0.1cm accuracy) and a square angle. Whenever possible, women stood on level ground next to a vertical surface. Height and weight measurements were used to compute a body-mass-index (BMI) for each woman. Children's weights and heights were not measured, as not all children were always available during data collection.

Ingredients in mixed dishes obtained from the 24-hour recall were quantified by: 1) weighing directly; 2) using home measures (e.g. scoop, heaped tin) and converted with standard food densities; or 3) estimated from locally purchased items (e.g. tomato, cabbage). The volume of cooked mixed dishes was computed using the pot circumference or diameter and food height. When no recipe was provided (e.g. ate at neighbours) or the recipe and yield were contradictory, an average recipe, based on

10 randomly selected household recipes within the survey, was used to estimate nutrient intakes.

Portions served were estimated by the women placing dried beans into the individual's bowl to represent the serving. When leftover food was reported, the leftover volume was estimated using the dried beans and removed, leaving the portion consumed. The beans representing the portion consumed were weighed and the bean density used to estimate the volume of food consumed. The same dried beans were used throughout. The quantity of mixed dish ingredients consumed was computed as a fraction of the recipe yield. Liquid food intakes, mainly tea and thin porridge (uji), were estimated from the mass of water in the individual's cup or from the commercial volume for purchased beverages. Food and beverage intakes were used to compute diet quality indices and to estimate nutrient intakes.

3.3.4 Data analysis

Milk intake and dietary diversity (DD) were estimated from results of the 24-hour recall. Dietary diversity was computed using a nine food group indicator, with a 15g minimum intake, validated for use in resource-poor settings (Wiesmann et al., 2009). The mean DD number was computed for each membership group.

Energy, distribution of dietary energy, and nutrient intakes were computed using the World Food Dietary Assessment System Version 2.0 (Wfood2) and the Kenyan food composition database (Bunch & Murphy, 1997). Foods not found in this database were imported from other databases within Wfood2 or imputed from USDA or Canadian Nutrient File values. Median (plus 1st and 3rd quartile) nutrient intakes were computed. Wfood2 estimates bioavailable iron and zinc intake using adjustments for enhancing and inhibiting factors in the same meal. Both iron and zinc status was assumed to be basal for these availability adjustments.

Women's energy intakes were examined for over- and under-reporters, using a high basal metabolic rate (Wiesmann et al., 2009) and the "Goldberg method"(Black, 2000). Data for women with energy intake outside the range 5230 and 17400 kJ (1250 and 4160 kcal) were examined for errors and plausibility and excluded from analysis as applicable. Data from nursing women were also excluded.

Women's milk consumption, energy, percent energy sources, and DD were analysed to examine associations with membership status and membership duration, using t-test or ANOVA with Bonferroni multiple comparison adjustment. Associations of diet quality indicators with membership duration were examined using linear regression. Children's milk consumption, energy, and percent energy distribution were compared between members and non-members using t-tests for normally distributed variables and Mann-Whitney for variables not following a normal distribution. Normal distribution was assessed using the Shapiro-Wilks test and transformations were applied to some variables to achieve a normal distribution.

Estimates of the prevalence of inadequate intakes (PII) were computed using the Estimated Average Requirement (EAR) cut-point method method (Carriquiry, 1999, Food and Nutrition Board, 2007), except (i) women's energy intake was compared against 9414 kJ (2250 kcal), the average energy requirement per day for Kenya (FAO, 2010), (ii) calcium was assessed using adequate intake (AI) values, and (iii) protein and available zinc and iron requirements were estimated using women's ages, weights (or median study group weight, 61.4 kg, for 20 women without measured weight), and mean requirements (and for women under 50 years, 0.48 mg iron/day requirement was added for menstrual losses); and (iv) children's energy, protein, and available iron and zinc requirements were compared against the childrens' mean requirements based on mean age and 25th percentile weight for age (Food and Nutrition Board, 2007, Murphy, Beaton, & Calloway, 1992; World Health Organization, 2007a). Significant associations of PII among membership groups (women only) and between members and non-members were examined using Chi^2 analysis.

Recipe calculations were performed using Excel (Microsoft v 6). Statistical analysis was conducted using Stata 10 (Stata Corp. College Station, TX). Significance was assessed at $p<0.05$ for women and, with the small sample size, at $p<0.10$ for children.

Approval to conduct the study was obtained through Farmers Helping Farmers, Wakulima Dairy Ltd., and the UPEI Research Ethics Board prior to conducting the study. Written consent was obtained from all participants after the nature of the study had been fully explained to them.

3.4 Results

All dairy group members approached agreed to participate in the survey (100% response). Women in two non-member households refused to participate, and the next household on the list was approached. Energy intakes were examined for over- and under–reporters. As a result, data from two women were excluded from the analysis. Intakes from other women with high or low energy were retained as data seemed probable, given other information. One woman being treated for anemia was excluded.

Women's age increased with membership duration, as expected, and ranged from 35 in the 1-3 and 4-6 year groups, to 43 and 53 in the 7-9 and 10+ year groups. The average age of women members (41.5) and non-members (43.9) was not different. Age and proportion of girls and boys were not different between member and non-member children (age 8.6 and 8.4 respectively).

3.4.1 Diet quality indicators

Milk intake was higher for member children and women compared to non-members (Table 3-1). Member women with lactating cow(s) had significantly higher milk intake than those without lactating cow(s). A similar trend was observed for non-member women with and without lactating cow(s). Women's milk intake was also positively associated with membership duration (data not shown; $R^{2} = 0.17$)[6].

Member women had higher energy intakes and weight status (BMI) than non-members (Table 3-2). Women's over-weight status (BMI≥25) was associated with dairy group membership, with 54% of members and 29% of non-members classified as overweight. In addition, members had higher percentage of energy from ASF (%ASF[7]) and saturated fat compared to non-members. Membership duration was negatively associated with the percentage of energy from carbohydrates (CHO) (R^2 0.11), and positively associated with the %ASF (R^2 0.17) and percentage of energy from saturated fat (R^2 0.13).

[6] Chapter 3 appendix includes data not shown in the published research paper, added for the thesis
[7] %ASF will be used throughout to indicate "percentage of dietary energy from animal source foods"

Similarly, member children consumed more energy than non-member children, and had lower percentage of energy from CHO and higher %ASF and percentage energy from fat compared to non-members (Table 3-3). Energy from flesh foods (meat, fish and poultry) was negligible for all women and children.

Dietary diversity was greater for member women than non-members but not different among membership duration groups (Table 3-4). Few women, in any group, consumed organ meat, eggs, or flesh foods.

3.4.2 Nutrient intake and prevalence of inadequate intake

Member women had higher median intake of macronutrients and most micronutrients (except thiamin, niacin, folate, and vitamin C) than non-members (data not shown). Women's micronutrient intakes per kJ were positively associated with membership duration for riboflavin, vitamin B12, vitamin A from ASF, calcium, and available zinc. Phytate densities of women's diets were not different between members and non-members.

Member women had lower PIIs for energy, protein and micronutrients, except thiamin, niacin, zinc, and iron, compared to non-member women (Table 3-5). Longer WDL membership duration was associated with lower PIIs for riboflavin, vitamin B12 and calcium and a higher PII for niacin (data not shown).

Children from member households had significantly higher intake of protein, fat, animal source vitamin A, calcium, riboflavin, vitamin B6 and vitamin B12, compared to non-members (data not shown). The PIIs for member children were significantly lower for riboflavin, folate, and vitamin B12, and marginally lower for energy (p=0.11) (Table 3-5). The prevalence of inadequate intake for vitamin B12, calcium, zinc, and iron, was >40% for all children.

Women's median daily sodium intake was 1155mg (670–1725 mg interquartile range). Sodium intake was not different among WDL groups but was positively associated with membership status. One quarter of all women exceeded the recommended population average sodium intake (2000 mg) (World Health Organization, 2007b); and this proportion was significantly greater for members (31%) compared to non-members (14%)[8].

3.5 Discussion

3.5.1 Diet quality indicators

Previous studies have reported higher household milk consumption with higher dairy farm productivity (Nicholson, Thornton, & Muinga, 2004; Kisusu et al., 2000; Mullins et al., 1996; Nicholson, Mwangi, Staal, & Thornton, 2003). Our study revealed that WDL member women and children consumed significantly more milk. Median milk intake for member children (201g) indicated that 50% of member children had the potential to achieve the health, growth, and cognitive benefits associated with the daily consumption of 200 mL of milk (Grillenberger et al., 2006; Murphy, Gewa, Grillenberger, Bwibo, & Neumann, 2007; Neumann & Harris, 1999; Siekmann et al., 2003). Member women's milk consumption was significantly higher with a lactating cow than without a lactating cow. A similar trend was observed for non-members, although the low numbers limited the statistical power. Farm management to reduce the 'dry period' for cows, and/or ownership of >1 cow with

[8] The proportion of members and non-member women with high sodium was added into the thesis after publication of the research paper; data shown in Chapter 3 appendix

varied lactations, is therefore likely to have nutritional benefits for women and children.

Milk in Kenya is primarily consumed in tea, and the proportion of milk in the tea can vary widely. Tannins in tea reduce iron bioavailability (Zijp, Korver, & Tijburg, 2000), and if member women and children are drinking more tea, there may be a negative impact on iron status; this merits further investigation. Consumption of less milk than promoted ('2 cups' daily) by member children may be due, in part, to limits in the amount of tea a child can consume, and reinforces the need to promote milk consumption. Milk intake from the 24-hour recall was lower than our reported average per-capita household milk (0.6 L/person/day) (Walton et al., in review) which suggests that average per-capita household milk may over-estimate individual milk consumption when assessing the impact of dairy intensification. This difference may be explained by uneven intra-household allocation, sharing milk or tea with visitors and neighbours, or using milk for calf rearing.

Our survey was conducted in August 2009 prior to harvest and following a drought and crop failure, when food shortages occurred (Wodon & Zaman, 2010, World Vision 2010). Member women had a lower PII for energy that corresponded with their higher median weight status, that may relate to staple foods (e.g. maize, flour) being available on credit to members. Despite higher median energy intake for member children, the PII for energy was high for members and non-members. Some instances of under-reported energy may have occurred. In one study, when children were not available to modify food intakes reported by their mothers, energy intakes were under-reported by 13% –19% (Gewa, Murphy, & Neumann, 2007). However, comparisons between groups would still likely be valid, with non-differential under-reporting, although the PII figures for children may be slightly inflated. Children's protein intake was mostly adequate, as expected with the traditional diet (Beaton, Calloway, & Murphy, 1992).

Members' energy distribution was in line with WHO recommendations in contrast to non-members (WHO/FAO, 2002). Members had higher %ASF and DD that indicated higher diet quality compared to non-members (Wiesmann et al., 2009). Women members' median %ASF reflected Kenyan food availability estimates (11%) (FAO, 2005). A wide range of %ASF has been reported, from 40% for Egyptian women (Calloway, Murphy, Balderston, Receveur, & Lein, 1992), 26-32% for dairy farm women in Rift Valley, Kenya (Huss-Ashmore, 1996), 3-12% for women in resource-poor settings (Arimond et al., 2010), to 0-4% for poor Ethiopian women (Ayele & Peacock, 2003). Three-quarters of member children exceeded 4% energy from ASF observed for Kenyan school children (Grillenberger et al., 2006), but few reached the 11% available ASF in Kenya (FAO, 2005) or the 9.8-12% reported for urban Ugandan children (Yeudall et al., 2007).

The positive association of women's %ASF with membership duration suggests nutritional benefits of sustained WDL membership. The higher %ASF, even for long-term members, was explained by milk, not flesh food, consumption. Animal source food consumption is often limited by resources. Our 24-hour recall method may not have been sufficiently sensitive to detect an increase in consumption of flesh foods, if there was one. Using a food frequency questionnaire, 86% of Tanzanian dairying households reported consuming meat/fish more than five times per month compared with 56% of non-dairy households (Lwelamira et al., 2010). Future studies could benefit from inclusion of food frequency data that may reflect broader changes to the dietary pattern associated with dairy group membership duration. Modestly higher DD may reflect access to rented land (Walton, VanLeeuwen, Yeudall, & Taylor, 2012) that enabled members to grow a greater variety of food crops, and/or that dairy income enabled the purchase of additional (non-ASF) foods.

3.5.2 Micronutrients

Members had significantly higher micronutrient intakes and lower PII values that reflected higher energy, %ASF, and DD. Milk nutrients figured prominently in associations of womens' nutrient intakes and PII with membership duration. Benefits to member's health and productivity, and specifically children's Vitamin B12 status, are expected (Murphy et al., 2003; Siekmann et al., 2003). Lower PII for vitamin C and folate can be attributed to higher dietary diversity (leafy greens, other fruits and vegetables). Despite positive change, micronutrients PII's remained high for women and children and reflected relatively low dietary diversity and intake of flesh foods (Arimond & Ruel, 2004; Arimond et al., 2010; Murphy et al., 2007). Inadequate intakes have negative inter-generational impacts that include poor pregnancy outcomes, reduced or delayed infant growth and development, and reduced personal health and productive capacity.

Children's high PII for zinc, in contrast with women's, may be related to children's lower energy and milk intake and their high zinc requirement. High seasonal consumption of mangoes, by children but not women, may explain children`s lower PII's for vitamins A and C (Gewa et al., 2007; Wiesmann et al., 2009). Seasonal differences in food patterns and dietary diversity of Ghanian, Malawian and rural Benin children have also been reported (Ferguson, Gibson, Opare-Obisaw et al., 1992; Mitchikpe, Dossa, Ategbo, Van Raaij, & Kok, 2009).

3.5.3 Nutrition transition

Women's weight status and intakes of saturated fat and sodium were examined, as even small income increases have been associated with a transition from under to over-nutrition. This transition is characterized by the consumption of a "Western diet" (high in saturated fat, sugar and refined foods, and low in fibre) and is associated with a higher prevalence of chronic disease (Popkin, 2002). The higher proportion of overweight member women reflects this transition and is an area of concern. Energy from saturated fat remained below the recommended level (10%), and median saturated fat intake was lower than the 17.2 g previously reported for a sample of rural Kenyan women considered to be undergoing the nutrition transition (Steyn, Nel, Parker, Ayah, & Mbithe, 2011). However, energy from saturated fat and sodium (per kJ) were positively associated with membership duration, and thus warrant further attention

Limitations in this research need to be considered in the interpretation of the results. First, the cross-sectional design limits conclusions concerning causality of dairy group membership (or duration) and specific outcomes. Stratified random sampling, although preferable, was not possible necessitating the use of chain referral sampling. To reduce potential bias from chain referral sampling, the survey list was generated using multiple chains, initiated through individuals with a wide range of age, geographic location, and involvement within the dairy group. Further research, using a longitudinal study design and a randomized sample, would help fulfill the criteria for causality needed to conclude the hypothesized “impacts” of WDL membership.

Second, the use of a single 24-hour recall, and inability to adjust for usual intake, leads to greater variability in the nutrient intake distributions. The resulting intake estimates are valid for comparing medians across groups (Gibson, 2005a; Willett, 1998). Using unadjusted intakes to estimate PIIs may over- or under-estimate these values. In addition, pregnant women were not identified systematically, and their higher nutritional requirements were not factored into analyses. This could lead to an underestimation of women`s PIIs, although this would likely be a non-differential bias among both members and non-members. As a result, our PIIs are valid for comparison between groups in this study, but may have limited comparability in other situations. A four pass 24-hour recall, with trained interviewers, was used to maximize the food recall and local measures used to maximize the accuracy of measurements (Kigutha, 1997) however, random error may still be involved in these estimates. For example, women may deliberately over- or under-report intakes if motivated by pride or seeking aid. This potential error was addressed, in part, by clearly explaining the nature and purpose of the study in advance and through appropriate exclusion of observations with unlikely high and low energy intakes. All reasonable efforts were made to accurately measure heights and weights, although it was sometimes a challenge to find a suitable level surface. The non-differential error resulting from small inaccuracies in height measurement should not detract from the importance of the BMI findings.

Third, we were unable to assess membership duration for children's intakes due to lower than expected numbers of children. Consequently, member and non-member school children were compared. Children's intakes may be under-reported when children were not available to contribute to the intake estimation (Gewa et al., 2007). This may limit comparability of our results, but comparisons between groups within the study remain valid.

Finally, the comparison of our zinc, iron and vitamin A results may be limited. Intakes reported here were corrected for absorption enhancing (e.g. vitamin C) and inhibiting factors (e.g. phytate, tannins). As well, the bioconversion factors for beta-carotene (1:12) and other carotenoids (1:24) to vitamin A (RE) were half that previously used, based on more recent evidence (Weber & Grune, 2012).

Our study presents positive dietary associations with semi-commercial dairy farming, within a dairy group, that can potentially improve member women and school children's health and livelihood capacities. Our results contrast those of cash-cropping schemes in six developing countries in African, Asia and Latin America that had no short term positive or adverse nutritional effects (Kennedy, Bouis, & von Braun, 1992). Others suggested the higher prevalence of malnutrition among children in Western Kenya was due to parents being involved in cash-crop farming rather than mixed farming (Kwena & Baliddawa, 2012). Although diets were predominantly inadequate they got modestly better, not worse, with semi-commercial dairying. These results highlight the need to modify the typical diet of rural Kenyan women and children, and support assertions that increased income from dairy was used for purchases other than nutritious food (Nicholson, et al., 2004; Mullins et al., 1996). To enhance positive and mitigate negative nutritional effects of dairy projects, activities should be expanded to include nutrition education, numeracy, literacy, and complementary agricultural activities. Such activities were associated with positive nutrition impacts in a dairy goat production project (Ayele & Peacock, 2003). A review of agricultural interventions revealed that investing in >3 of the recognized livelihood assets, in particular nutrition education of women, had the greatest nutritional impact (Berti et al., 2004; Smith & Haddad, 2000), which is in keeping with the recommendation for more productive collaborations between agricultural and nutritional sciences (Demment, Young, & Sensenig, 2003).

Specific strategies for dietary modification, within this limited resource setting, include strengthening efforts to increase children's milk consumption, initiating complementary interventions to enable the consumption of nutrient dense foods (e.g. flesh and organ meats, fruit and vegetables), and promoting the use of food-based strategies that improve zinc and iron bioavailability in plant foods (Gibson, 2005a).

3.6 Conclusions

Duration of membership was associated with lower prevalence of inadequate intake for some micronutrients, particularly those from milk. WDL membership was associated with higher energy and intake of micronutrients however, the prevalence of inadequate intakes of a number of micronutrients remained unacceptably high for WDL member women and children. Diets reflected relatively low dietary diversity and women and children remain at risk of under-nutrition, even with long-term dairy group membership. These results highlight the need to modify the typical diet of rural Kenyan women and children and the need for nutrition interventions to accompany agricultural interventions. In addition, member women's weight status and trends in saturated fat and sodium consumption represent areas of concern and there is a need to monitor nutrition transition measures within development initiatives.

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Table 3-1. Median (1^{st}, 3^{rd} quartile) milk consumption (g) for women and children, by membership and cattle ownership and cow lactation status

	Non members	n	All members	n
Women (all)	162^a (55, 267)	20	440^b (288, 758)	82
Children	37^a (0, 90)	16	201^b (98,360)	46
Women (no cattle)	108 (27,268)	8	570	1
Women (cattle, none lactating)	165^a (88,243)	8	267^b(206,411)*	18
Women (lactating cow)	256^a (92, 374)	4	500 ^{b}(360,892)*	63

[a,b] mean values within a row with different superscript letters were significantly different (p<.05)
*t-test; (p<.05) member women with a lactating cow consumed more milk than members without a lactating cow

Table3-2. Dietary energy, weight status, and energy distribution (median, 1st, 3rd quartile) for women, by membership and membership duration groups *

	Non members n=20	All members n=82	Membership duration groups: 1-3 yrs n=21	4-6 yrs n=20	7-9 yrs n=19	10+ yrs n=22	Reference values
Energy (kj)	5786[a] (4655,8625)	10180[b] (7029,13130)	10259[b] (7310,13129)	11912[b] (8893,14097)	8916[ab] (6427,12573)	8556[ab] (6780,10757)	9414[†]
Weight status (BMI)	22 (20, 25)[a]	25 (23, 29)[b]	27 (22, 30)	24 (22, 28)	26 (24, 28)	24 (23, 26)	
%energy from protein	11 (10, 14)	12 (11,14)	13 (11, 13)	13 (10, 14)	12 (12, 14)	12 (11, 14)	10-15%[‡]
%energy from CHO	80 (73, 82)[a]	72 (66, 77)[b]	76 (72, 80)[ab]	70 (62, 78)[ab]	70 (68, 76)[ab]	69 (65, 75)[b]	55-75%[‡]
%energy from fat	14 (12, 20)	19 (13, 25)	16 (12, 20)	20 (12, 28)	22 (16, 25)	19 (17, 26)	15-35%[‡]
%energy from SAT	3.5 (2.6,4.9)[a]	5.4 (4.1, 7.2)[b]	4.6 (3.9,6.2)[ab]	5.2 (3.6,7.1)[ab]	5.6 (4.5,7.0)[ab]	6.1 (4.8,7.4)[b]	< 10%[‡]
%energy from ASF	6.5 (2.6, 9.7)[a]	12 (7, 17)[b]	10 (6.3, 13)[b]	11 (7.3, 16)[b]	12 (6.6, 18)[b]	15 (9.4, 21)[b]	11%[§]

BMI, body-mass index. CHO, carbohydrate. SAT, saturated fat. ASF, animal source foods.
[a,b] mean values within a row with different superscript letters were significantly different (p<.05)
[*] variables were transformed before analysis
[†] 9414 kJ (2250 kcal) average energy requirement per day for Kenya[31]
[‡]WHO guidelines [34]
[§] Kenya food supplies %energy from ASF[13]

Table3-3. Dietary energy distribution (median, 1st, 3rd quartile) for school age children, by membership

	Non-members n=16	Members n=46	WHO guidelines
Energy (kJ)	50 (3625,8420)[a]	7225 (5744,10113)[b]	
%energy from protein	11 (10, 12)	11(10,13)	10-15%*
%energy from carbohydrate	80 (77,85)[a]	74(68,77)[b]	55-75%*
%energy from fat	13 (11,19)[a]	19(14,27)[b]	15-35%*
% energy from ASF	2.2 (1.0,5.8)[a]	6.6(4.1,11)[b]	

ASF, animal source foods
[a,b] values with different superscript letters within a row were significantly different
*WHO guidelines[34]

Table 3-4. Women's dietary diversity: % of women consuming each food group and mean (standard error) dietary diversity score, by membership

	Non-members n=20	All members n=82
Starch	100	100
Legumes/nuts	82	76
Dairy (milk)	95	100
Organ meats	0	2
Eggs	5	6
Flesh foods	9	8
Leafy greens (vitamin A)	32[a]	55[b]
Other vitamin A fruit/vegetables	27	31
Other fruit/vegetables	64[a]	87[b]
Dietary diversity score	4.1 (0.19)[a]	4.7 (0.10)[b]

[a,b] values with different superscript letters within a row were associated with membership ($p<0.05$)

Table 3-5. Women's and children's prevalence of inadequate intake, by membership

	Women		Children	
	Non-members n=20	All members n=82	Non-members n=16	Members n=46
Energy	80[a]	44[b]	69	44
Protein	43[a]	18[b]	6	4
Thiamin	20	11	0	0
Riboflavin	70[a]	13[b]	36[a]	13[b]
Niacin	45	43	25	13
Vitamin B6	50[a]	13[b]	0	0
Folate	40[a]	18[b]	19[a]	4[b]
Vitamin B12	100[a]	61[b]	88[a]	63[b]
Vitamin A	65[a]	38[b]	38	22
Vitamin C	50[a]	23[b]	6	2
Calcium	100[a]	61[b]	100	87
Zinc	20	14	50	39
Iron	70	65	63	59

[a,b] values with different superscript letters within a row were associated with membership ($p<0.05$), women and children were analysed separately

3.8 Additional data

Table 3-6 . Women's nutrient intakes by membership group with reference Estimated Average Requirement (EAR) or Adequate Intake (AI) (reference women age 19-50) [1]

				Membership duration groups			
	EAR[2]	non	All members	1-3 yrs	4-6 yrs	7-9 yrs	10+ yrs
Kilocalories	2200	**1383** (1112, 2061)a	**2433**(1680,3138)	2452 (1747, 3138)b	2847(2125, 3370)b	2131 (1536, 3005)ab	2045 (1621, 2571)ab
Protein (g)		**40** (31, 53)	**73**(55,97)	76 (63, 88)	84 (58, 104)	68 (51, 97)	64 (48, 114)
Carbohydrates (g)		**265** (216, 384)	**434**(304,551)	445 (330, 532)	479 (395, 567)	403 (274, 551)	340 (264, 457)
Fat (g)		**26** (14, 37)	**48**(29, 72)	42 (29, 54)	62 (29, 93)	48 (32,71)	48 (24, 89)
Thiamine (mg)	0.9	1.3 (0.9, 2.3)	1.7(1.2,2.7)	1.9 (1.6, 3.0)	1.8 (1.2, 2.1)	1.8 (1.1, 3.0)	1.4 (0.9, 2.1)
Riboflavin (mg)	0.9	**0.8** (0.6, 1.1)	**1.6**(1.2,2.2)	1.5 (1.2, 2.1)	1.7 (1.0, 2.4)	1.7 (1.1, 2.3)	1.4 (1.2, 2.0)
Niacin (mg)	11	12 (6.8, 15)	12(8.4,19)	14 (11, 19)	12 (8.6, 19)	14 (8.4, 21	9.4 (6.7, 17)
Vitamin B6 (mg)	1.1	**1.1** (0.8, 1.7)	**1.8**(1.5,2.9)	1.9 (1.6, 3.0)	2.1 (1.6, 3.1)	1.8 (1.4, 2.6)	1.7 (1.3, 2.4)
Folate (ug)	320	**396** (247, 526)	**654**(401,865)	666 (505, 850)	747 (373, 881)	655 (423, 875)	490 (220, 824)
Vitamin B12 (ug)	2.0	**0.8** (0.2, 1.1)	**1.7**(1.2,3.2)	1.6 (1.4, 2.0)	2.0 (0.7, 3.7)	1.6 (0.9, 3.1)	2.2 (1.1, 3.4)
Vitamin A ASF		**52** (16, 75)	**134**(90, 221)	118 (102, 140)	146 (53, 236)	125 (69, 270)	153 (112, 245)
Vitamin A (RE)	500	**248** (122, 662)	**828**(356,1320)	903 (688, 1279)	780 (302, 1110)	1139 (376, 1369)	726 (266, 1155)
Vitamin C	60	60 (43, 90)a	89(62, 145)	108 (79, 145)b	95 (58, 176)ab	87 (64, 145)ab	74 (41, 113)ab
Calcium (mg)	800	**303** (154, 452)	**765**(542,1111)	739 (549, 885)	790 (456, 1180)	797 (477, 1290)	768 (569, 1111)
Zn (mg) available	[3]	**1.2** (0.7, 1.6)a	**1.7**(1.1,2.6)	1.5 (1.1, 2.3)ab	1.9 (1.1, 2.8)ab	1.7 (0.9, 2.8)ab	1.8 (1.2, 2.9)b
Iron (mg) available	[4]	**0.7** (0.5, 1.1)	**1.0**(0.7,1.6)	1.3 (0.8, 1.6)	1.0 (0.7, 1.5)	1.1 (0.7, 1.6)	0.7 (0.5, 1.4)
Sodium (mg)	2000[5]	1004 (566, 1500)	1502(858,2143)	1502 (1231, 2373)	1711 (1080, 2232)	1372 (858, 1677)	1120 (569, 2044)

[1] Data are expressed as median (first, third quartile) and were Log transformed for ANOVA; Measurements in the same row followed by different letters are significantly different**; Bold** indicates significant difference between members and non-members

[2] EAR from IOM (2010) Calcium value for adequate intake; For women age 51-65 differences: Calcium AI 1000 mg; Vitamin B6 1.3 mg/day

[3,] zinc in high phytate diet – requires 12.7 ug/kg available zinc per day for women >19 years

[4] Iron in low heme and ASF diet requires 14 ug/kg available iron per day for women > 19 years (Wfood); for women ≤50 average add 0.48mg per day for menstrual losses

[5] Sodium intake maximum recommended (WHO, 2007b)

Table 3-7. Women's prevalence of 'inadequate' intake; % below EAR or AI (Adequate intake) by membership group[1]

	Non n=21	All members n=85	Membership duration groups 1-3 yr n=23	4-6 yrs n=20	7-9 yrs n=19	10+ yrs n=23
calories	**80a**	**44**	38b	25b	53ab	59ab
protein	**43**	**18**	13	2	21	17
thiamin	20	11	9.5	5.0	5.3	22.7
riboflavin	**70**	**13**	4.8	20	16	14
Niacin	45	43	24	40	42	64
Vitamin B6	**50**	**13**	5	15	11	23
Folate	**40**	**18**	14	15	16	27
Vitamin B12	**100a**	**61**	81ab	50b	63b	50b
Vitamin A	**65a**	**38**	19b	45ab	32b	41ab
Vitamin C	**50**	**23**	14	25	21	32
calcium[2]	**100**	**61**	67	55	58	63
Zinc[3]	20	14	9.5	15	16	9.1
Iron [3]	70	65	57	65	68	64

[1]**Bold** indicates significant difference between members and non-members;
Measurements in the same row followed by different letters are significantly different;
[2] proportion of group below AI; EAR unknown
[3] Zinc and Iron PII computed with available mineral intake and computed available mineral requirement

Table 3 8. School Children's nutrient intake[1]

		Boys			Girls		
	EAR	Non-members n=11	Members n=22	p	Non-members n=5	Members n=24	p
Kilocalories	[2]	1272 (896,1901)	1998(1501, 2464)	0.02	889 (844, 2124)	1649 (1044, 2315)	0.36
Protein (g)		34 (22,54)	59(37, 74)	<0.01	28 (26, 62)	42 (29, 68)	0.53
Carbohydrate (g)		287 (190,387)	363(266,472)	0.09	203 (167, 432)	272 (191, 388)	0.82
Thiamine (mg)	0.5	1.0 (.7, 1.9)	1.6 (1.0, 2.8)	0.15	1.8 (1.3, 2.6)	1.0 (0.7, 1.6)	0.09
Riboflavin (mg)	0.5	0.6 (.5, 1.0)	1.2 (0.8, 1.8)	<0.0	0.6 (0.5, 1.2)	1.0 (0.8, 1.2)	0.69
Niacin (mg)	6	8.1 (5.5, 15.9)	12.7 (7.9, 23.6)	0.18	13.1 (10.2, 19.4)	8.5 (5.8, 14.4)	0.19
Vitamin B6 (mg)	0.5	1.2 (0.6, 1.8)	1.6 (1.2, 2.3)	0.07	0.7 (0.6, 1.6)	1.3 (0.9, 2.0)	0.22
Folate (ug)	160	259 (146, 525)	502 (325, 717)	0.04	368 (323,669)	354 (232,592)	0.58
Vitamin B12 (ug)	1.0	0.07 (0, 0.24)	0.8 (.5, 1.5)	<0.01	0.3 (0.2, 0.9)	0.8 (0.4, 1.1)	0.33
Vitamin A ASF		15 (0, 30)	64 (34, 138)	<0.01	20 (18, 62)	58 (36, 84)	0.21
Vitamin A (RE)	275	541 (55, 1368)	716 (371, 1150)	0.72	97 (70, 702)	859 (310, 1436)	0.13
Vitamin C (mg)	22	82 (30, 130)	96(68, 194)	0.18	50 (42, 119)	96 (42, 141)	0.77
Calcium (mg)	800	166 (89, 214)	450 (339, 562)	<0.01	143 (66, 474)	372 (254, 532)	0.12
Zn available (Basel) (mg)	[4]	0.5 (0.3,1.3)	1.2(0.6, 1.7)	0.05	1.5 (1.2, 1.9)	1.1 (0.6, 1.3)	0.07
Iron (mg) available	[5]	0.6 (0.5,1.1)	0.9(0.6, 1.4)	0.20	0.5 (0.5, 1.0)	0.7 (0.6, 1.6)	0.97
Sodium (mg)		672 (371,1050)	1067 (878, 1481)	0.01	567 (543, 1066)	819 (612, 1454)	0.29

[1]Data are expressed as median (first, third quartile).
[2] energy requirement estimated using 25th percentile weight for age Boys 1728 Girls 1590kcal
[3] protein requirement estimated using Wfood and 25th percentile weight for age Boys 20g Girls 19.6g
[4] available zinc using Wfood and 25th percentile weight Boys .76, girls .74mg
[5] available iron using Wfood and 25th percentile weight Boys .81, girls .79mg

4 Chapter 4 Determinants of household food security and diet quality among the sustainable livelihood assets of Kenyan dairy group farm women

4.1 Abstract

Kenyan community leaders formed Wakulima dairy group in 1992 as a means to strengthen the livelihoods for farmers on small farms in central Kenya. Enhanced sustainable livelihood assets, food security and women's diet quality have been reported for these farmers. Objectives of this study were to identify significant determinants of household food security (HFS) and diet quality among dairy group membership status and duration and livelihood assets to help target future activities and resources. A cross-sectional study was conducted with dairy group members (n=88) across four membership-duration groups (1-3, 4-6, 7-9 and 10+ years) and non-members (n=23) living among members. Demographics, farm features, HFS and diet (24-hour recall) were assessed. Diet quality indicators, including percent energy from animal source foods (%ASF), dietary diversity (DD), and mean nutrient adequacy ratio (MAR), were computed from 24-hour recalls. Linear and logistic modeling was used to identify significant determinants of HFS and diet quality indicators from demographic and farm characteristics. HFS was assessed as a determinant of each diet quality indicator.

Households with 4-6, 7-9, and 10+ years dairy group membership were 4.6, 5.5 and 8.7 times more likely, respectively, to be food secure than non-members ($p<0.05$). Smaller households, >primary education for men, milk production (kg/cow/day), women's group membership, and the number of consumer assets were positively associated with higher odds of HFS in multivariable logistic models. HFS was positively associated with diet quality measured as %ASF and MAR but not DD. DD was higher

with women's group membership. Evidence for significantly higher odds of HFS after three years of dairy group membership is important for development and funding agencies in setting project goals and measurable targets. Support for women and secondary education for women and men were associated with higher HFS and diet quality. Although %ASF (from milk consumption) was positively associated with membership duration, the low DD and MAR reflected micronutrient-deficient diets, even with HFS. There is a need to increase the nutrient density of diets of rural Kenyan women and to understand factors influencing food choices.

4.2 Introduction

The majority of the world's poor in developing countries live in rural areas, and many depend on small farms for food and income. Enhancing agricultural productivity of these smallholder farmers is one means of improving national food availability and household food security (HFS) (FAO, 2003; Matshe, 2009).

HFS exists when all members have access to food throughout the year, in quantity, variety, safety, and cultural acceptability, necessary to maintain an active and healthy life; and are not at excessive risk of losing such access (Moron, 2006). There is strong evidence that chronic food insecurity is associated with changes to women's health and nutrition including dietary intake (Maxwell, 1996), lower micronutrient intakes (Tarasuk & Beaton, 1999), anaemia, obesity (Jayne, Scrimgeour, Polhemus, Otieno, & Bovill, 2011), and decreased mental health (El-Sayed et al., 2010; Hadley & Patil, 2006). Evidence of impact in terms of increased risk of low birth-weight infants (Neumann & Harrison, 1994), higher risk of infant and young child mortality (Campbell et al., 2009), and delayed and limited physical, academic, and psychosocial development of children (Alaimo, Olson, & Frongillo, 2001; Gorman, 1995, Whitaker, Phillips, & Orzol, 2006) also exists.

The typical high-starch, plant-based diets in developing countries lack diversity. This diet places women, infants, and school-age children at risk of multiple micronutrient deficiencies (Arimond & Ruel, 2004; Arimond et al., 2010; Best, Neufingerl, van Geel, van den Briel, & Osendarp, 2010). In Kenya, 35% of children under-five years are stunted, an indicator of long term under-nutrition (Kenya National Bureau of Statistics (KNBS) and ICF Macro., 2010) and a high proportion of Kenyan children and non-pregnant women had mild to severe deficiencies of serum zinc (51 and 52%, respectively), hemoglobin (iron) (73 and 56%, respectively), and retinol (vitamin A) (84 and 51% respectively) (FAO, 2005; Kenya Ministry of Health, 1999).

Wakulima Dairy Ltd. (WDL), in central Kenya, has over 6000 active member farmers, and provides a market for raw milk, dairy training for women and men, and other supports (Moron, 2006, Bebe, 2003). Positive associations of WDL membership with milk production and consumption, dairy income, HFS, diet quality, and well-being measures were previously reported (Walton, VanLeeuwen, Yeudall & Taylor 2012; Walton, Taylor, VanLeeuwen, Yeudall, & Mbugua, accepted for publication). There is a need to identify livelihood and household factors associated with improved HFS and diet quality to guide policy and interventions toward improved food and nutrition security.

The objectives of the research were to (1) assess WDL membership status and duration as predictors of household food security and diet quality and, (2) identify significant determinants of HFS and diet quality among WDL membership duration and household and farm factors.

4.3 Methods

4.3.1 Study design

A cross-sectional survey was conducted in August 2009 among 88 WDL member households, evenly distributed over four membership-duration groups (1-3, 4-6, 7-9 and 10+ years), and 23 non-member households.

4.3.2 Study site

The 6,000 WDL members live throughout Mukurwe-ini Division and represent approximately 29 percent of the area's population (estimated at 84,000 in 2009) (Kenya National Bureau of Statistics, 2009). Non-member farmers live amidst the members.

4.3.3 Sampling

A sample size of 20 households in each of the four membership-duration groups (1-3, 4-6, 7-9 and 10+ years) was established to generate data with reasonable power, balanced with limited resources, to conduct the research. Ten percent oversampling per group was included to compensate for spoiled or missing data. There was no central list of WDL members with duration status or contact information and no reasonable and efficient manner to establish a database to allow stratified random sampling. As a result, study participants were identified using chain referral sampling. This method is used to access "hard to reach" populations (Heckathorn, 2002; Penrod, Preston, Cain, & Starks, 2003) and creates the sample by referrals made among people (members) who know others possessing the "character of interest" (membership-duration) (Biernacki & Waldorf, 1981). Eight WDL members, representing a wide range of age, geographic distribution, and involvement within WDL, were selected to initiate the referrals. Each initiator referred members in the four membership-duration groups. The research team contacted referred members to confirm membership-duration and this procedure repeated until sufficient numbers of members in each group were identified. Referred members were asked to identify non-members to generate a list (n=50) from which non-member participants (n=23) were randomly selected. WDL directors and managers, and teachers, were excluded to focus the research on households with farming as their primary livelihood strategy.

4.3.4 Questionnaire

The survey tool included questions on household demographics, farm and household environment, household food security, and food intake. Demographic and household environment questions were selected and modified from the Kenyan Demographic and Household Survey (Central Bureau of Statistics (CBS) [Kenya], Ministry of Health (MOH) [Kenya], and ORC Macro, 2004). Our questionnaire is described elsewhere in more detail (Walton, VanLeeuwen, Yeudall, & Taylor, 2012). HFS was measured using the "Household Food Insecurity Access Scale" (HFIA) version3 (Coates, Swindale, & Bilinsky, 2007). This tool explores anxiety over food access and the need to reduce food quality or quantity in the previous 4 weeks and places households into four ordinal levels of increasing food insecurity. Food secure and mildly insecure categories were merged to create a 'food secure" category, while moderately and severely insecure categories were merged to create a 'food insecure' category (Gewa, Oguttu, & Yandell, 2011). Women's food intake was collected using a four-pass 24-hour recall (Gibson, 2005).

The questionnaire was modified to improve cultural understanding after review by WDL management and pre-testing prior to use. The interview was conducted in person by two trained interviewers, including the first author, using a translator, as needed.

Interviews were conducted to ensure each day of the week was evenly represented in the food recalls for each membership group. Farm and household questions were posed to the husband and wife, depending on availability. The person responsible for food preparation, usually the woman, was interviewed alone (when possible) for HFS and 24-hour recall.

4.3.5 Diet quality

Methods used to quantify women's food and nutrient intakes, and assess over and under reporters, are described elsewhere (Walton, et al., accepted for publication). Briefly, ingredients in individual household recipes were quantified in local measures and the quantities, in the portions consumed, computed from the cooked recipe volume. Nutrient intakes were computed using World Food Dietary Assessment System 2.0 and the Kenyan nutrient database (Bunch & Murphy, 1997). Nutrients for foods not in this database were imported from other Wfood2 databases or imputed from USDA or Canadian Nutrient File values. Women's energy intakes were examined using a high basal metabolic rate (Wiesmann, Arimond, & Loechl, 2009) and the "Goldberg method" (Black, 2000). Data for women with energy intake outside the range 5230 and 17400kJ (1250 and 4160 kcal) were examined for errors and plausibility and excluded from analysis as appropriate. Data from nursing women were excluded.

Food and nutrient intakes were used to compute diet quality indicators: 1) dietary diversity (DD), computed using nine food groups with a 15 g minimum intake cut-off (Wiesmann et al., 2009); 2) percent energy from animal source foods (%ASF[9])(Allen, 2003; Yeudall, Gibson, Cullinan, & Mtimuni, 2005); and 3) mean nutrient adequacy ratio (MAR). MAR was estimated from the mean of eleven nutrient adequacy ratios (NAR), (thiamin, riboflavin, niacin, folate, vitamins B6, B12, C, A, calcium, zinc, and iron) each limited to 1.0. NAR (Becquey et al., 2010; Raffensperger et al., 2010; Wiesmann et al., 2009; WHO/FAO, 2004). Calcium, with no set RNI at the time of the study, was

[9] %ASF will be used throughout to indicate percent of dietary energy from animal source foods

classified according to the method of Foote (Foote, Murphy, Wilkens, Basiotis, & Carlson, 2004); with the NAR=0 for intake $\leq$25% of the established level for Adequate Intake (AI); NAR=0.25 for intake 25-50% of AI, NAR=0.5 for intake 51-75%; and NAR=0.75 for >75-100%; and NAR=1.0 for intakes above the AI. The NAR for iron was computed using RNI for 5% bioavailability, and for zinc using low (15%) bioavailability.

4.3.6 Data analysis

Descriptive statistics were examined for each variable. Transformations (e.g. square root) were applied to some continuous variables, and the normality of transformed distribution confirmed using the Shapiro-Wilks test. Milk production (kg/cow/day) quartiles were computed from data for households owning at least one lactating cow at the time of the survey (n=69). Households without dairy animals (n=11) and without lactating cows (n=31) were assigned "zero" milk production. A dummy variable for father's education was generated for single women and widows (n=17) or when his education was unknown (n=3).

Data were coded and manually entered using Microsoft Excel 2007 and checked for accuracy using range checks. Logistic and linear regression models were used to identify predictors of HFS and diet quality (%ASF, DD, MAR), respectively. Significant variables from univariable regression analyses were retained for multivariable model building ($p \leq 0.20$). Potential explanatory variables were tested for collinearity using Pearson correlation coefficients for continuous variables, logistic or linear regression for continuous with categorical variables, and chi-square test for two categorical variables. In cases of highly correlated variables ($p < 0.05$) the one of most interest or with more reliable measurement was included in model building. Potential explanatory variables were included in a possible causal diagram to avoid including intervening variables in model building processes. Backward manual selection was used to determine significant predictors ($p \leq 0.20$) in the multivariable models. The final models were compared to an automated backward stepwise model-building process, which generated the same models in all cases (variable entry at $p \leq 0.20$). The likelihood-ratio test was used to compare logistic models with and without an additional predictor. Goodness-of-fit of the final logistic model was examined using the Hosmer-Lemeshow test. Fit of the linear models was examined using adjusted R^2 values. The Cook-Weisburg test and graphical examination of standardized residuals were used to examine for heteroskedasticity. Observations with high residuals or leverage were examined for errors, plausibility, and influence. Statistical analyses were conducted using Stata 10.

Approval to conduct the study was obtained through Farmers Helping Farmers, a partner non-governmental organization based in Prince Edward Island, Canada, WDL, and the Research Ethics Board at the University of Prince Edward Island, prior to conducting the study. Written consent was obtained from all participants after the nature of the study had been fully explained.

4.4 Results

All dairy group members (n=88) approached agreed to participate in the survey (100% response). Two non-member households refused to participate, and the next household on the list approached to obtain the desired sample size (n=23). Examination of energy intakes resulted in data from two women being excluded. Intakes from other women with high or low energy were retained as data seemed probable, given other information. One woman being treated for anemia was excluded.

4.4.1 Food Security

Demographic, farm, and household characteristics of the study population are in Table 4-1. Sixty-six percent of households were classified as food insecure. Univariable associations of HFS with WDL membership-duration and farm and household characteristics are in Table 4-2.With the exception of short-term member households (1-3 years), WDL members had significantly higher odds of reporting food security compared to non-members. Ten of 14 household and farm variables had significant univariable association with HFS ($p<0.05$). WDL membership status (member vs. non-member) was strongly correlated with all variables that had a significant association with HFS. In order to investigate other determinants of HFS, the variable for WDL membership was excluded from multivariable modeling.

Two multivariable logistic models for HFS were generated (Table 4-3). Husband's education level and household size variables were significant in both models. Of 20 households with missing husband's education, 17 were headed by women. This coefficient is therefore indirectly interpretable as "woman as head-of-house", and significant in the second model. Higher odds of HFS were predicted with husband with >primary education and lower odds with a larger household. In the first model, women's group membership and the number of consumer assets were also positive determinants of HFS. The second model was constructed to examine per-cow milk production and excluded variables indicative of longer-term economic stability (i.e. concrete floor, consumer assets, herd size). Milk productivity was a significant predictor of HFS in the multivariable model with husband's education level and household size. The odds and probabilities of HFS were computed with milk production quartiles and predicted a 47% probability of being food secure for households with 75th percentile milk production, over double the probability of households with no milk production (22%) (Table 4-4). Goodness of fit analysis indicated both models fit the data (Hosmer-Lemeshow test = 0.50 and 0.66 for models 1 and 2, respectively), with no influential observations.

4.4.2 Diet quality

Women's %ASF ranged from 0 to 30%, with a median of 9.8% (IQR 6.2 to 15.6%); MAR ranged from 0.12 to 1.0 with a median of 0.81 (IQR 0.66 to 0.88); DD ranged from 2 to 7 (of 9 food groups) with a median of 5 (IQR 4 to 5). MAR and %ASF were significantly correlated ($p<0.05$). Overall, less than 1/3 of women consumed flesh foods, organ meat, eggs, or "other vitamin-A fruits and vegetables", all nutrient rich foods (Figure 4-1). All women consumed starch foods and most (95%) consumed dairy products. Almost 50% of women consumed dark green leafy vegetables.

Univariable associations of WDL membership duration, household characteristics, and HFS with women's diet quality indicators are in Table 4-5. WDL membership explained a portion of the variation in %ASF (R^2=0.14), DD (R^2=0.04), and MAR (R^2=0.19), although only %ASF had a positive membership duration relationship. HFS was significantly ($p\leq0.05$) and positively associated with %ASF and MAR, but not DD (p=0.62). In addition, HFS was significantly and positively associated with women's dietary energy intake. Median energy intake, overall, was 8933 kJ (2135 kcal) with an interquartile range (IQR) of 6150-12573 kJ (1470-3005 kcal) and was 10607 kJ (2535 kcal) for food secure women compared to 8033 kJ (1920 kcal) for food insecure women ($p<0.05$).

Multivariable regression results for %ASF, DD and MAR, in Tables 4-6, 4-7, and 4-8, have coefficient values similar to those in univariable regressions. MAR and %ASF were transformed for modeling therefore coefficients are not directly interpretable. Positive predictors of %ASF were milk production (kg/cow/day) and husbands job income (>5000 Ksh/month); household size was negatively associated with %ASF (Table 4-6). Predicted %ASF for women in four and six member households, by milk production quartiles, are in Figure 4-2 to aid in the interpretation of the coefficients.

Women's group membership and mother's age were significant predictors of DD (Table 4-7). Each 10 years of advancing age was associated with a 0.2 lower DD, while women's group members had 0.4 higher predicted DD. MAR was positively predicted by HFS, mother's education and milk production (Table 4-8). Mother's education (>primary education) and HFS (food secure household) had similar coefficients predicting 0.07 higher MAR from a baseline of 0.71 from a household with no milk production. Predicted values for MAR are in Table 4-9 to aid interpretation of the model. The predicted MAR was 0.08 higher with 75th percentile milk production. No significant interactions were found among predictors in the diet quality models and no observations were influential. Models had modest predictive ability (R^2=0.06–0.19).

4.5 Discussion

Smallholder dairy farming in Kenya, as in many developing countries, has the potential to provide households with regular income and greater food and nutrition security (Bebe, 2003; Thorpe, Muriuki, Omore, Owango, & Staal, 2000).

4.5.1 Food security

WDL membership was a significant positive predictor of HFS. Similarly, cooperative membership for rural Nigerian households was associated with HFS (Amaza, Adejobi, & Fregene, 2008). These findings align with the importance transforming structure, such as rural agro-industries and organizations, in strengthening livelihoods (Bebe, 2003; Gitau, Gitau, & Waltner-Toews, 2009; Jaleta, Gebremedhin and Hoekstra, 2009; Moron, 2006). Our evidence of higher odds of HFS with longer membership-duration suggested the strengthening of livelihood assets was gradual and associated with positive food security outcomes, particularly since the research was conducted amid the 2008 world food price crisis, a drought in Kenya, country-wide disruptions following the 2008 election, and a 41% increase in Kenyan maize prices (World Vision, Wodon & Zaman, 2010). Others have reported that households may struggle to acquire the first cow to enter dairy farming (Rangnekar & Thorpe, 2002). Our study provides evidence of an extended struggle to strengthen livelihoods, as the odds of food security of 1-3 year-members was not different from non-members. Alternately, it may be that food insecurity comes with short term membership for some households, as previously food-secure households may stretch their resources to become dairy group members. Assigning causality and specific outcomes is limited by the cross-sectional study design. A longitudinal study would be useful to confirm causal relationships.

Similar to other studies (Ahmed, Jabbar, & Ehui, 2000; Amaza et al., 2008; Leroy, 2001; Muluken, Bogale, & Negatu, 2008; Shariff & GeokLin, 2008), we found HFS associated positively with husband’s formal education level and negatively with household size. Female-headed households had higher odds of household food security compared to households headed by males with only primary education. Male-headed households in Nigeria also had a greater probability of being food insecure (Amaza, 2008) whereas findings of Muluken, Bogale, & Negatu (2008) in Ethiopia found that sex of the head-of-household was not a significant predictor of household food security. This variability may be related to cultural aspects of each country. Greater access to education and health services has been recommended to address household size and increase food security (Amaza et al., 2008; Leroy, 2001; Muluken et al., 2008). Consistent with our results of positive associations of women's group membership with HFS, others have suggested reducing constraints for women farmers significantly contributes to reducing food insecurity (Cubbins, 1991; Herz, 1989, Quisumbing, Brown, Feldstein, Haddad, & Pena, 1995). Measures of human capital were significantly associated with HFS which supports the assertion that a strong complement of human capital (skills, knowledge and ability) is required to make use of other assets, and to allow adaptations of livelihood strategies (Karanja et al., 2010).

Our study found higher, locally relevant, per-cow milk production positively associated with odds of HFS. These findings extend our understanding of enhanced dairy farm productivity and HFS from proxy measures in Ethiopia (Ahmed et al., 2000) and Tanzania (Lwelamira, Binamungu, & and Njau, 2010) and demonstrates positive outcome of measures to increase production efficiency (Amaza et al., 2008; Leroy, 2001). Our results suggested that households should work toward higher milk production and having more than one dairy cow, to ensure minimal periods without milk production, for higher HFS. Similarly, others have concluded that productivity enhancing measures remain underexploited (Hildebrand, 2008). This situation may be related to time constraints and limited access to extension services that affect women more than men, and may limit the participation and efficiency of women in livestock production (Kristjanson et al., 2010; Yisehak, 2008). As well, it is not uncommon for commercialization and higher profitability to lead to more male control of activities and incomes (Huss-Ashmore, 1996; Kristjanson et al., 2010; Gladwin, Thomson, Peterson, & Anderson, 2001). The majority of Kenyan smallholder dairy farm women had full or partial control of dairy income control (Mullins, Wahome, Tsangari, & Maarse, 1996), including those in our study (Walton et al., 2012), which likely factored into the positive production and HFS results. However, the desire to retain this control may be a limiting factor in efforts to increase productivity, as women may want to keep production levels modest. This situation warrants further research and affirms the need for gender roles to be explored and managed within agricultural productivity enhancement initiatives.

Comparability of our results to those of other studies may be limited by the HFS questionnaire (HFIA Version3) which may not have cross-cultural validity (Deitchler, Ballard, Swindale and Coates, 2010). However, the questionnaire was culturally adapted, as recommended, and therefore results are valid within the context of our study.

4.5.2 Diet quality

In a chronically food-insecure setting, associations among diet quality, improved agricultural production, and HFS are not well established. Higher milk production, income, HFS and diet quality have been associated with improved dairy-cow health and breeding in Kenya (Kisusu, Mdoe, Turuka, & Mlambiti, 2000; Mullins et al., 1996), Tanzania (Bayer & Kapunda, 2006), and Ethiopia (Ahmed et al., 2000). Enhanced dairying in Kenya was associated with higher household DD, caloric intake, and nutritional status (Huss-Ashmore & Curry, 1992) and, in Tanzanian households, with more frequent (per month) consumption of meat and fish (Lwelamira et al., 2010). Others have reported increased food purchases and average per-capita milk consumption (Leroy & Frongillo 2007). In our study, WDL members had higher %ASF, MAR and DD but only %ASF (derived from milk consumption) was associated positively with WDL membership duration which supports suggestions that additional dairy-derived income is used for non-food expenditures (Nicholson, 1999) or that production income may be used to purchase foods that do not improve nutrient intakes (Randolph et al., 2007).

Food secure women had higher food (energy) intake and %ASF and MAR. However, similar to other observations in Kenya (Huss-Ashmore, 1996), DD was not associated with HFS. The nutritional impact of higher %ASF (primarily from milk) is limited in light of low DD reflecting reports that few women consumed organ meats, flesh foods and eggs. Consequently, inadequate intakes of iron and zinc are expected (Gibson, Yeudall, Drost, Mtitimuni, & Cullinan, 1998). As well, in Kenya, milk is mainly consumed in tea, and if women are drinking more tea, higher tannin intake will inhibit plant-source iron absorption and could negatively impact their iron status (Zijp, Korver, & Tijburg, 2000). This situation warrants further examination.

Women's age and education, women's group membership, milk production, off-farm income and household size were associated with diet quality indicators. The predicted effect of higher milk production (10 kg per-cow; 75th percentile) increased MAR from 0.71 to 0.79, which is on par with the predicted effect of being food secure or the mother having greater-than-primary education. Milk production at this level represents a realistic short-term goal to improve diet quality, for households with limited education and in a food insecure environment. Research to identify and alleviate barriers to higher milk production is warranted.

Low predicted DD and MAR indicate that women are at risk of inadequate micronutrient intakes. Women's groups may be a route, in the short term, to promote a more nutrient dense diet, although the nature of involvement would need to be defined. Longer term, our findings point to the importance of women's educational attainment. Similarly others have found women's education was effective to reduce the rate of child malnutrition (Smith & Haddad, 2000).

Finding younger age predicted modestly higher DD was encouraging, considering that positive health and pregnancy outcomes have been associated with greater DD (Arimond et al., 2010). The lower DD among older women may negatively influence the diets of grandchildren in their care, unless they are reducing their diversity in order to provide for the grandchildren. This situation warrants further investigation in light of evidence that paternal grandmothers in Malawi make dietary decisions for their grandchildren (Kerr, Dakishoni, Shumba, Msachi, & Chirwa, 2008).

The low adjusted-R^2 values indicate that WDL membership, HFS, and farm and household variables explain only a portion of the variation in women's diet quality. Our use of a single 24-hour recall did not allow adjustment for usual intake, which could have narrowed MAR and %ASF variances and improved predictive abilities. Efforts were made to maximize the quality of the dietary intake data, including the use of a four pass 24-hour recall, trained interviewers, and the use of local measures (Kigutha, 1997), however, random error may still be involved in these estimates. For example, women may deliberately over- or under-report intakes if motivated by pride or seeking aid. This potential problem was addressed, in part, by clearly explaining the purpose of the survey, carefully evaluating extreme observations, and making appropriate exclusions. Pregnant women were not identified systematically. Their higher nutritional requirements could result in overestimated MAR values for these women but any bias would likely be non-differential among members and non-members with similar average age (Walton et al., 2012).

Our findings strengthen the evidence that market-oriented dairy farming, with productivity enhancement, is important to enhance HFS, and enable greater food energy intake, and to enhance women's diet quality (%ASF and MAR) derived from milk consumption. Off-farm income and husband's education factor into HFS and %ASF, potentially through support to increase milk productivity, whereas women's education and social support factored into diet quality measures that were less strongly associated with milk consumption (DD and MAR). Our results suggest that the choice of milk as the market-oriented commodity is important for diet quality because of the importance of consuming food from their own production and of milk as a source of some important micronutrients. However, other initiatives, potentially mediated through women's groups, are needed to improved DD and low micronutrient intakes in order to more fully address dietary intake, as one determinant of nutrition security. It is also recognized that enhanced dairy income can benefit nutrition security through improved access to health care or environmental hygiene (UNICEF, 1997). The negative association of larger household size, combined with evidence that fertility rates are inversely related to higher education (Crouch, 1992), reinforces the importance of education to alleviate malnutrition.

Limitations in this research project need to be considered in the interpretation of the results. The cross-sectional survey design limits conclusions concerning causality and specific outcomes. Stratified random sampling, although preferable, was not possible necessitating the use of chain referral sampling. To reduce potential bias from chain referral sampling, the survey list was generated using multiple chains, initiated through individuals with a wide range of age, geographic location, and involvement within the dairy group. Random selection of eligible referred participants on this list was utilized, as much as possible and practical. Further research, using a longitudinal study design and a randomized sample, would help fulfill the criteria for causality needed to conclude the hypothesized impacts.

4.6 Conclusions

Longer duration of WDL membership was associated with higher odds of household food security (HFS). Odds of HFS were low for newer members, which suggested that at least three years of WDL membership, to strengthen livelihood capacities, is needed for a measureable difference in food security status for dairy group members involved in semi-commercial production. Practitioners and funding agencies should consider this time in project goal-setting.

Stronger human capital and per-cow milk production were associated with higher odds of HFS and better diet quality for women. Measures to enable women farmers to purchase a cow, achieve higher milk production, eventually own >1 dairy cow to ensure a continuous milk supply, meanwhile retaining control of the resources and income, are therefore recommended in this context. Promoting and strengthening women's groups are suggested to advance HFS and diet quality benefits and may help women farmers realize farm productivity enhancement. Membership in WDL likely enabled the food and nutrition security outcomes with higher milk production, by providing a reliable market for the surplus milk among other supportive roles.

A negative association between large households and HFS and diet quality reinforces the need to curb large families. The positive benefits of formal education beyond primary school, for females and males, was demonstrated for HFS and women's diet quality, and can be anticipated to influence the health, fertility rates, and capacity of individuals and households in the long-term. To more sufficiently address low quality diets for women, there is a need to understand factors influencing women's food choices, and for appropriate interventions to promote and enable a more nutrient dense diet.

4.7 References

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Table 4-1. Population characteristics of participating Kenyan households (n=111)

Variable	Median	Mean (se)	Range	Kenyan average*
Mothers age (years)	39	42 (1.2)	21-75	
Husband's age (years)	44	48 (1.6)	24-88	
Number in household	4	4.3(0.17)	1-10	4.6 (rural)
Number of cattle	2	1.9(0.12)	0-6	
Milk production (kg/cow)†	6.5	7.2(0.51)	1-23	
Assets (SES proxy)	2	2.4(0.12)	0-6	

		%	Kenyan statistics* (%)
Husband's education‡	none or primary	67	58.1‖
	some secondary and higher	33	41.7‖
Mothers education§	none or primary	70	70.9‖
	some secondary and higher	30	28.9‖
Husband's job	none or <5000 ksh/month	82	
	>5000 ksh/month	18	
Head-of-household	woman	17	
	man	83	
Floor (SES proxy)	dirt	69	74*
	tile & concrete	31	26
Additional land	do not rent	56	
	rent	44	
Water	river water throughout the year	35	45.8
	non-river at least part of the year	65	53.8**
Women's group‡	not member	34	
	member	66	
Food security	not secure	66	
	secure	34	

SES, socioeconomic status

* Kenyan National Bureau of Statistics (KNBS), 2010 Kenyan Demographic Household Survey

†n=69; 38% of households did not have lactating cows at the survey time

‡n=91; 18% of households did not report husband's education (unknown, no husband in household)

§ n=109 - two households were without women

‖ KNBS, education for Kenyans age 20 – 65+, by gender

¶ KNBS, 'dirt floor' percentage includes 'dung floor'

**KNBS, % of households using any improved water source

Table 4-2. Univariable logistic regression associations of dairy group membership duration and socio-economic household characteristics as predictors of food security among 111 Kenyan farm households

	Odds Ratio (CI[*])	p-value
Membership duration		<0.01 (global p)
Non-member	(reference group)	
1-3 year	1.4 (0.28-7.1)[†]	0.68
4-6 year	4.6 (1.1-20.3)	0.04
7-9 year	5.5 (1.2-24.4)	0.03
10+ years	8.7 (2.0-37.6)	<0.01
Demographic variables		
Mothers age (years)	2.1 (0.6, 8.1)	0.26
Husband's age (years)	0.8 (0.2, 3.1)	0.69
Husband's education > primary	5.2 (2.0, 13.7)	<0.01
Husband's education (missing)[‡]	5.6 (1.9, 16.6)	<0.01
Mothers education > primary	1.2 (0.5, 2.6)	0.76
Woman head-of-house	3.3 (1.2, 9.1)	0.02
Number in household	0.6 (0.5 ,0.8)	<0.01
Financial		
Husband's job >5000 ksh/month	2.9 (1.1, 7.7)	0.04
Milk production (kg/cow)	1.1 (1.0,1.2)	0.03
Assets (SES proxy)	1.5 (1.1, 2.1)	0.02
Floor (SES proxy)	3.2 (1.4, 7.5)	0.01
Physical		
Number of cattle	3.1 (1.2, 8.2)	0.02
Rent additional land	1.5 (1.1, 2.1)	0.20
Water	7.9 (2.5, 24.3)	<0.01
Social		
Women's group member	4.2 (1.6, 11)	<0.01

SES, socioeconomic status
[*] CI, 95% confidence interval
[†] OR and p-values are relative to non-members for each membership group
[‡] category for 'husbands education', for households without husband's education specified (widowed, single, unknown) is not directly interpretable; indirectly interpreted as female-headed-households

Table 4-3. Multivariable logistic regression models of household food security among 111 Kenyan farm households

	Model 1–livelihood model (pseudo R^2=0.26)			Model 2 – production model (pseudo R^2=0.22)		
	Coefficients (CI*)	Odds Ratio (CI*)	p-value	Coefficients (CI*)	Odds Ratio (CI*)	p-value
Husband's education >primary	1.62(0.53, 2.71)	5.07 (1.71,15.0)	<0.05	1.81 (0.74,2.88)	13.8 (3.7,48.7)	<0.05
Husbands education (missing)†	1.26(-.06, 2.57)	3.51 (0.94,13.1)	0.06	1.54 (0.33,2.75)	6.10 (2.10,17.8)	<0.05
Number in household‡	-0.48(0-0.83,-0.14)	0.62 (0.44, 0.97)	<0.05	-0.42 (-0.75,-0.09)	0.66 (0.47,0.91)	<0.05
Women’s group membership	1.27(0.13, 2.40)	3.56 (1.14, 11.1)	<0.05			
Asset (SES proxy)	0.56(0.14, 0.97)	1.74 (1.14, 2.64)	<0.05			
Milk production (kg/cow/day)				0.12 (0.02, 0.21)	1.12 (1.02, 1.23)	<0.05
Constant	-1.84(-3.85,0.16)		0.07	-1.33 (-2.50,-0.20)		<0.05

SES, socioeconomic status

* CI, 95% confidence interval

† ‘husband’s education’ (missing) for households without specified husband’s education (widowed, single, unknown) is interpreted as female-headed household

‡ households with 1 and 2 members were combined as baseline

Table 4-4. Predicted odds and probability of households being food secure with 25th, 50th, and 75th percentiles of milk production (kg/cow) among 111 Kenyan farm households

	Odds Ratio (CI*)	Predicted probability
No milk	1.0 (referent	0.22
25th 4 kg †	1.6 (1.1, 2.3)	0.31
50th 6.5 kg	2.1 (1.2, 4.0)	0.37
75th 10 kg	3.2 (1.3, 8.4)	0.47

* CI, 95% confidence interval

† milk production quartiles computed from households with lactating cows

Table 4-5 Univariable linear regression results of dairy group membership duration and socio-economic household predictors with three indicators (outcomes) of women's diet quality among 102 Kenyan farm households

	%ASF* coefficient (CI‡)	p value	Dietary diversity coefficient (CI‡)	p value	MAR† coefficient (CI‡)	p value
Membership duration§		<0.01		0.17		0.01
Non-member (constant) ‖	2.46(2.03, 2.89)	<0.01	4.1 (3.7,4.5)	<0.01	0.27(0.18,0.37)	<0.01
1-3 years	0.76(0.16, 1.36)	0.01	0.63(0.08,1.2)	0.02	0.30(0.17,0.43)	<0.01
4-6 years	0.80(0.19, 1.41)	0.01	0.53(-0.01,1.1)	0.06	0.29(0.15,0.42)	<0.01
7-9 years	0.95(0.34, 1.57)	<0.01	0.39(-0.17, 0.95)	0.17	0.28(0.14,0.41)	<0.01
10+ years	1.34(0.74, 1.93)	<0.01	0.52(-0.01,1.04)	0.06	0.25(0.12,0.38)	<0.01
Demographic variables						
Mothers age (years)	0.01(-0.00,0.03)	0.11	-0.01(-0.02,0.00)	0.10	-0.002(-0.01,0.00)	0.32
Husband's age (years)	0.01(-0.01,0.12)	0.65	-0.01(-0.03,0.00)	0.05	-0.002(-0.01,0.00)	0.20
Husband's education > primary	-0.16(-0.64,0.32)	0.52	0.00(-0.41,0.41)	1.00	0.10(-0.01,0.21)	0.07
Mother's education >primary	0.25(-0.20,0.71)	0.27	0.28(-0.11,0.66)	0.16	0.13(0.03,0.23)	0.01
Woman head-of-household	0.49 (-0.5,1.04)	0.08	-0.02 (-0.15,0.11)	0.75	-0.26 (-0.72,0.21)	0.27
Number in household	-0.11(-0.22,0.00)	0.06	0.06(-0.04,0.16)	0.23	-0.02(-0.04,0.01)	0.25
Financial						
Husband's job >5000 ksh/month	0.69(0.16,1.22)	0.01	0.31(-0.13,0.76)	0.17	0.08(-0.05,0.20)	0.22
Milk production (kg/cow)	0.08(0.04,0.12)	0.01	0.01(-0.02,0.05)	0.49	0.02(0.01,0.02)	<0.01
Assets (SES proxy)	0.08(-0.09,0.24)	0.24	0.17(0.03,0.30)	0.02	0.05(0.02,0.09)	<0.01
Floor (SES proxy)	0.62(0.20,1.05)	<0.01	0.36(-0.01,0.73)	0.05	0.12(0.02,0.22)	0.02
Physical						
Number of cattle	0.26(0.10,0.43)	<0.01	0.05(-0.09,0.19)	0.47	0.07(0.03,0.10)	<0.01
Rent additional land	0.39(-0.02,0.80)	0.06	0.30(-0.05,0.65)	0.09	0.09(0.00,0.19)	0.04
Water access	0.40(-0.02,0.83)	0.06	0.13(-0.24,0.51)	0.48	0.13(0.04,0.23)	<0.01
Social						
Women's group member	0.31(-0.12,0.74)	0.16	0.35(-0.02,0.71)	0.06	0.10(0.00,0.19)	0.05
Food secure household	0.42(-0.01,0.86)	0.05	0.09(-0.27,0.46)	0.62	0.13(0.03,0.22)	0.01

SES, socioeconomic status
*%ASF, percent energy from animal source foods, square root transformed for normal distribution
†MAR, mean (micronutrient) adequacy ratio, cubed for normal distribution
‡ CI, 95% confidence interval
§p-value for membership duration refers to overall p for model
‖each membership duration group p value is relative to the non-member, constant

Table 4-6 Significant predictors of women's percent energy from animal source food (%ASF)* in multivariable linear regression models among 102 Kenyan farm households ($R^2 = 0.19$)

	Coefficient (CI†)	p-value
Number in household	-0.10 (-0.20, 0.01)	0.07
Husband's job	0.57 (0.08, 1.06)	0.02
Milk production (kg/cow)	0.07 (0.04, 0.11)	<0.01
Constant	3.14 (2.60, 3.68)	<0.01

*% energy from ASF, square root transformed for normal distribution
†CI, 95% confidence interval

Table 4-7 Significant predictors of women's dietary diversity in multivariable linear regression models among 102 Kenyan farm households ($R^2 = 0.06$)

	Coefficient (CI*)	p-value
Mother's age	-0.02 (-0.03, -0.002)	0.03
Women's group	0.40 (0.04, 0.76)	0.03
Constant	4.92 (4.31, 5.54)	

*CI, 95% confidence interval

Table 4-8 Significant predictors of women's mean adequacy ratio (MAR*) in multivariable linear regression models among 102 Kenyan farm households ($R^2 = 0.15$)

	Coefficient (CI†)	p-value
Secure	0.10 (0.01,0.19)	.04
Mother's education	0.10 (0.01,0.20)	.03
Milk production	0.01 (0.003,0.02)	.01
Constant	0.37 (0.29,0.44)	

*Mean (micronutrient) adequacy ratio, cubed for normal distribution

†CI, 95% confidence interval

Table 4-9. Predicted values of women's mean (micronutrient) adequacy ratio (MAR) with household food security status, mother's education level and a range of milk production levels

	Not food secure		Food secure	
Education level	primary	>primary	primary	>primary
No milk	0.71	0.78	0.77	0.83
25th percentile (4 kg)	0.74	0.80	0.80	0.85
50th percentile (6.5 kg)	0.76	0.81	0.81	0.87
75th percentile (10 kg)	0.79	0.84	0.84	0.88

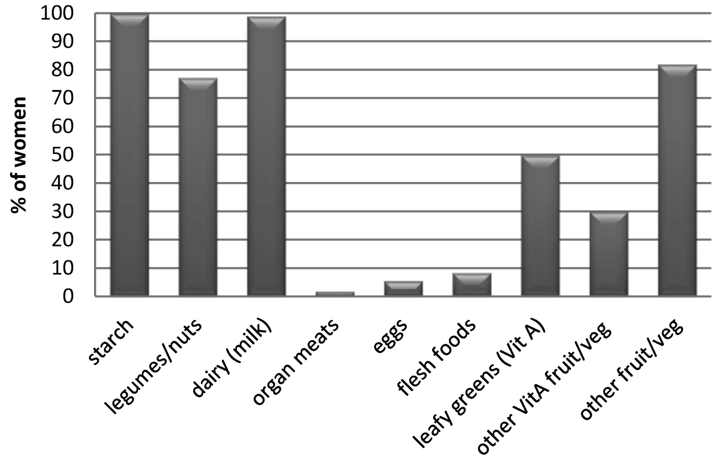

Figure 4-1. Percent of Kenyan farm women (n=102) consuming food (>15g) in nine dietary diversity food groups

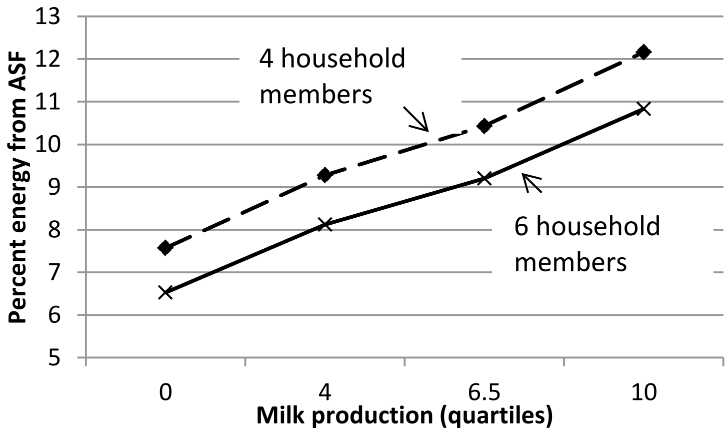

Figure 4-2. Predicted percent energy from ASF for women with husband's income <5000 Ksh/month, by milk production and number of household members.

5 Chapter 5 A controlled nutrition education trial among dairy group members and non-member rural Kenyan farm women

5.1 Abstract

Our previous results found women members of a community-based dairy group in central Kenya were more food secure and had modestly better diet quality compared with non-members. However, women had inadequate intakes of multiple micronutrients. To evaluate the effect of nutrition education on women's nutrition knowledge, practices, and food intakes, and the potential for an interaction of the education with Wakulima Dairy Ltd. (WDL) membership duration, a controlled trial was conducted. Random sampling from previously selected study groups, WDL members (n=88) in four membership duration groups (1-3, 4-6, 7-9 and 10+ years) and non-members (n=23), was used assign women to intervention and control groups. Nutrition knowledge, practices, dietary influences, and diet quality were assessed before and five months after the intervention. Diet quality indices were computed from results of 24-hour recalls, including percent energy from animal source foods (%ASF), dietary diversity (DD), and phytate:zinc molar ratio. Nutrition knowledge and practices and factors influencing dietary choices were assessed from semi-structured and open-ended questions.

Significantly more intervention-group women practiced phytate and tannin reduction strategies compared with control-group women, which is expected to improve zinc and iron bioavailability in their diets. More intervention-group women had knowledge of the nutritional importance of fruit and vegetables, specifically vitamin A sources, and a greater proportion of these women consumed dark green leafy (DGLV) and orange-flesh fruit and vegetables. A significant interaction of WDL membership status and nutrition

education on DD, vitamin A and vitamin C suggested that WDL members had greater capacity to improve their dietary diversity, while non-members made greater positive change in vitamin A and C intakes. Most women were satisfied with their diets, with the exception of wanting to eat more meat and eggs, which was limited by lack of money.

This study provides evidence for women's capacity to make positive dietary changes when informed. DD remained low among all women, despite the intervention. Food composition data for phytates and tannins, and models to account for their reduction on nutrient intakes, are needed to quantify reduction effects on iron and zinc intakes. To understand the effects of dietary modifications on nutrient status, biochemical testing of zinc, iron, and vitamin A is needed. Effective mechanisms for nutrition knowledge exchange and evaluation in the longer term are needed to more broadly address diet quality.

5.2 Introduction

The majority of the world's poor live in rural areas of developing countries, and many rely on small farms for food and income (IFAD, 2011). In sub-Saharan Africa, including Kenya, many smallholder farmers are challenged with low agricultural productivity, inadequate resources, and food insecurity (FAO, 2006). Plant-based high-starch monotonous diets are typical in developing countries, with limited consumption of vegetables, fruit and animal source food, and this places women at risk of inadequate intakes of multiple micronutrients (Arimond & Ruel, 2004; Arimond et al., 2010). Inadequate micronutrient intakes have been associated with limited immune function, physical and cognitive development, and caring and working capacity (Black et al., 2008; Grantham-McGregor et al., 2007; Hyder et al., 2005). Maternal and child under-nutrition is the underlying cause of 3.5 million deaths annually (Black et al., 2008).

To address multiple micronutrient deficiencies, food-based strategies are considered more appropriate and sustainable than fortification and supplementation, and more relevant in resource-poor areas with limited access to health services, including supplement distribution (Allen, 2003; Low et al., 2007). Food-based strategies, using an "empowerment education approach" that establishes a dialogue among all participants to assess their situations and identify strategies to address problems, have been successful for increasing nutritional knowledge and in changing dietary behaviors in a range of developing country settings (Bezner Kerr, Berti, & Shumba, 2010; Creed-Kanashiro et al., 2003; Yeudall, Gibson, Cullinan, & Mtimuni, 2005). Building capacity to increase and improve food production and availability is considered a holistic way to improve nutritional outcomes (Moron, 2006), although agricultural projects with specified nutritional objectives were associated with greater nutritional outcomes than agricultural projects alone (Ayele & Peacock, 2003; Berti, Krasevec, & FitzGerald, 2004; Leroy & Frongillo, 2007; Low et al., 2007).

Wakulima Dairy Ltd. (WDL) was established in 1992 and now has about 6000 independent member farmers throughout the Mukurwe-ini Division, Central province, Kenya. WDL has partnered with Farmers Helping Farmers (FHF), a Canadian NGO, since 1996, and with the Atlantic Veterinary College (AVC) since 2004, with support from the Canadian International Development Agency. Together theses partners have worked to improve dairy herd management, to increase milk production, and to strengthen the livelihoods of WDL's women farmers. WDL's primary business is to buy raw milk from its members and transport and sell the milk to available markets. In addition, WDL broadly supports members, including the provision of credit for veterinary services, farm supplies, school fees, and staple household foods. Our previous results revealed that, compared to non-members, WDL members consumed more milk and had higher dairy income, household food security, and the potential for improved health and wellness, with better quality homes, water access and social support. However, dietary diversity was low and there was a high prevalence of inadequate micronutrient intakes among women and children (Walton, Taylor, VanLeeuwen, Yeudall, & Mbugua, accepted for publication). Kenyan health officials have stated that dairy development initiatives should be accompanied by nutrition education programs that encourage households to consume more of the additional milk produced to achieve the full positive impact of the development initiatives (Nicholson, 1999). However, to our knowledge, no studies have comprehensively evaluated the effect of nutrition education in conjunction with capacity-building agricultural projects, or examined the interaction of dairy group membership duration, with nutrition education, on diet quality.

The primary objectives of the study were to determine the effects of a nutrition education intervention on (1) nutrition knowledge and practices, and (2) diet quality measures related to micronutrient intakes, and to determine whether the effects were dependent on WDL membership status or duration. A third objective was to explore factors influencing food choices that may influence the effectiveness of the nutrition intervention on diet quality measures.

5.3 Methods

5.3.1 Study site

The 6,000 WDL member households located throughout Mukurwe-ini Division represent approximately 29 percent of the division's population (estimated at 84,000 inhabitants) (Kenya National Bureau of Statistics, 2009). Members live along four rural routes, and in a village, among non-member farmers.

5.3.2 Study group

Women from previously selected study groups, WDL members (n=88) in four membership duration groups (1-3, 4-6, 7-9 and 10+ years) and non-members (n=23), were randomly assigned to intervention and control groups. Selection of the study groups, using a chain-referral system, was described elsewhere (Walton, VanLeeuwen, Yeudall, & Taylor, 2012). Sub-samples of 12 women, from intervention and control groups, were selected to be interviewed to explore factors influencing their food choices.

5.3.3 Nutrition education intervention

The nutrition education workshop content and format was planned and implemented by a local dietitian, a Kenyan nutrition research assistant from Egerton University, and the lead author, and supported by WDL Board of Directors. The intervention focused on the use of food-based strategies to increase vitamin A intake and improve bioavailability of iron and zinc. These target micronutrients were selected based on known deficiencies for women in Kenya (Arimond et al., 2010; UNICEF, 2008). Food based-strategies that were achievable using existing resources were selected in order to have the greatest potential for short-term impact, participation, and sustainability, (Moron, 2006; Tchibindat, Mouyokani, & Yila-Boumpoto, 2002; Ruel, 2001). The messages communicated the reasons behind, and demonstrated methods to:

(1) increase vitamin A intake by consuming foods high in pro-vitamin A, such as dark green leafy vegetables (DGLV) and dark orange-red flesh fruit and vegetables (OF);

(2) increase bioavailability of iron and zinc by:

   a. soaking (and draining) beans prior to cooking;
   b. curbing the consumption of tea within 2 hours (before or after) a meal; and
   c. consuming fruit rich in vitamin C with meals.

The intervention was based on the following rationale. Bioavailability of iron and zinc, from plant-based diets, is typically low due to the non-heme form of iron and the high molar ratios of phytates and tannins to non-heme iron and zinc (Davies & Olpin, 1979; Siegenberg et al., 1991). A reduction of phytate and tannin intakes is therefore desirable to improve iron and zinc bioavailability (Ali, Shuja, Zahoor, & and Qadri, 2010). Soaking beans, and discarding the soaking water prior to cooking, resulted in a greater reduction of phytates (58-65%) and tannins (58-81%) (Fernandes, Waleska, & Da Costa Proença, 2010; Shimelis & Rakshit, 2007) compared to beans cooked without soaking (25-28% phytate and 23-38% tannin reduction). The tannins from one cup of tea, consumed with the food, reduced the average iron absorbed from bread and rice with soup by almost 80% (Disler et al., 1975), and separation of tea drinking from food intake by 2 hours is recommended to improve iron bioavailability (Zijp, Korver, & Tijburg, 2000). Finally, ascorbic acid ($\geq$50 mg) consumed with a meal counters the negative impact of high (>100 mg) tannins, and enhances iron absorption (Siegenberg et al., 1991).

A brief message citing the nutritional benefits of eating moderate amounts of flesh foods, including liver and meat, was included to allay fears previously expressed by some women that meat was not healthy. Because meat is generally desired but its consumption is often restricted by lack of money (Gibson & Ferguson, 1998), this message was not a strong focus of the intervention.

The dietitian conducted the workshops, speaking to the Kenyan food pyramid (food-based dietary guideline) with a focus on the defined messages, probing the participants, and answering questions. Participants had the opportunity to taste typical foods prepared by a local chef according to the strategies being promoted. A local chef prepared githeri, a maize and beans stew, by soaking the maize and beans for 12 hours, draining, and then boiling them in fresh water until they were soft and fully cooked. The cooked maize and beans were mixed with fried onion and tomato, in a typical manner, and three types of indigenous DGLV (amaranthus, spider plant, and managu), and kale were chopped, added to the mixture, and cooked. Chapattis were prepared with mashed cooked orange squash (locally referred to as pumpkin). The nutrition research assistant stimulated discussion of the food samples, and promoted the nutritional and health benefit of the strategies.

Participants were provided with a handout that promoted the food-based strategies and with recipes and additional nutrition information. As well, participants received seeds and growing instructions for indigenous DGLV and orange pumpkin (squash), and a litre of vitamin A fortified vegetable oil. These were provided as tokens of appreciation for their participation in the trial and were selected to reinforce the vitamin A message.

Workshops were scheduled for mid-morning and early afternoon, at four locations throughout the division to best enable women to participate. The 2-3 hour workshops were held in August 2009. A member of the WDL board of directors was present to open and close each meeting. The intervention-group was asked to not discuss the nutrition workshop with other women until the workshops were held with the women in the control group. Control group workshops were held at the end of the post-intervention data collection period (February 2010).

5.3.4 Data collection

Face-to-face interviews were utilized for all data collection. Pre-intervention, household socio-demographic, food security, and farm characteristics were collected from all participants using a pre-tested questionnaire described in detail elsewhere (Walton, et al., 2012).

Pre- and post-intervention, all women's dietary intakes were assessed using a single four-pass 24-hour dietary recall (Gibson, 2005) and described elsewhere in detail (Walton et al. accepted for publication). Nutrition knowledge and practices were assessed pre- and post-intervention using an adapted structured questionnaire (Yeudall et al., 2005). Post-intervention, a semi-structured questionnaire was used to identify resources, knowledge, health, availability, preferences, other factors potentially influencing food choices. This questionnaire was based on information revealed during pre-intervention interviews and the nutrition workshop. The subsamples of intervention and control group women were interviewed to examine factors in food choices and the capacity for dietary changes using a series of open-ended questions that included:

(1) if participating in the study influenced their food choices, and what changes, if any, were made, what changes they would like to make, and challenges to making these changes;

(2) if they were aware of previously revealed attitudes; “eat them [fruit and vegetables] like they are food” and “eat like you will not eat tomorrow”, and if so, what each meant, and if and how these influenced their food habits; and

(3) their perception of if, and how, WDL membership changes what people eat.

Two teams conducted the interviews. Each team included a trained interviewer and a translator. All efforts were made to have the teams blinded as to the intervention status of the study participants. To ensure consistency in the administration of the open-ended questions, only one interview team, that included the lead researcher, asked these questions. Questions and probes were translated from English to Kikuyu (the local language) and back to English, and responses carefully recorded from the translated responses. In all cases, questions were posed to the main food preparer, usually the woman, in the household.

5.3.5 Data handling and analysis

Details of the methods used to examine socio-demographics, food security, and farm characteristics, and to estimate food portions and ingredients consumed, were previously reported (Walton et al., 2012; Walton et al., accepted for publication). Briefly, food and nutrient intakes were computed from the 24-hour food intakes using the World Food Dietary Assessment System Version 2.0 (Wfood2) and the Kenyan food composition database (Bunch & Murphy, 1997). Missing foods were imported from other databases within Wfood2, or imputed from USDA or Canadian Nutrient File values. Data were used to compute food (grams of foods in the DGLV, OF, and 'other fruit and vegetables' groups) and nutrient intakes, and three diet quality indicators; (1) dietary diversity was computed using a validated nine food group indicator with a 15g minimum intake that has been associated with women's micronutrient intakes (Arimond et al., 2010); (2) percent energy from animal source foods (%ASF) that is used to indicate consumption of zinc, iron, and other micronutrients found in abundant and bioavailable forms in animal foods (Allen, 2003); and (3) phytate:zinc molar ratios. Post-intervention, the intake of phytates from beans was reduced by 36% (Shimelis & Rakshit, 2007) for women soaking beans and the remainder added to phytate from other sources to estimate total phytate intakes. These adjusted phytate intakes were used to compute phytate:zinc molar ratios (using 660.3g/mol for phytate).

Nutrition knowledge and practices and the semi-structured questionnaire data were coded and manually entered using Microsoft Excel 2007 (Microsoft Office, Microsoft Corp. 2007). Responses from open-ended questions were examined for common responses and themes and coded and entered using Excel.

Descriptive statistics were computed for socio-demographics, food security, food and nutrient intakes and diet quality indicators for the control- and intervention-groups, pre- and post-intervention, and for the differences in dietary measures pre- to post-intervention. Outliers were checked for errors and accuracy. The distribution of continuous food and nutrient intakes and diet quality indicators was assessed visually and with the Shapiro-Wilks test. Transformations were applied to some variables (i.e., natural logarithm) and the normal distribution of transformed variables was confirmed using the Shapiro-Wilks test.

Pre-intervention comparability of socio-demographic, food security, nutrition knowledge and practices, food and nutrient intakes, and diet quality indices for the control- and intervention-groups was examined. Differences in proportions were assessed using a Pearson chi-square test. Two-sample t-tests were used to compare normally distributed variables with equal variances. Wilcoxon rank sum tests were used when no transformation was effective to achieve normal distributions with equal variances.

The effect of the intervention on the proportion of women consuming food in each DD food group was assessed using a Pearson chi-square test and post-intervention data. Effects of the intervention and of a WDL membership status-by-intervention status interaction on dietary measures (food and nutrient intakes and diet quality indicators) were examined using linear and logistic regression analyses. Pre- and post-intervention date data were used in the models to increase the statistical power. The potential for seasonal influence on diets was addressed by including date in the models. Food intakes were dichotomized using median intakes of DGLV (19g), OF (13g), and ‘other fruit and vegetables’(36g) as no transformations were effective to achieve normal distributions of these variables. Observations with high leverage and residuals were examined for data entry errors and for influence on model coefficients. Model fit was assessed using the adjusted R^2 for linear models and Hosmer Lemeshow goodness-of-fit test for logistic models. Statistical analyses were conducted using Stata 10 (Stata Corp. College Station, TX). Significance was assessed at $p<0.05$.

Approval to conduct the study was obtained through Farmers Helping Farmers, Wakulima Dairy Ltd., and UPEI Research Ethics Board prior to conducting the study. Written consent was obtained from all participants after the nature of the study had been fully explained to them.

5.4 Results

Pre-intervention socio-demographic characteristics and prevalence of food security were not significantly different between intervention- and control-groups which indicated that randomization was successful in distributing these characteristics evenly among the intervention- and control-groups (Table 5.1). Minor non-significant differences were observed; a higher proportion of intervention group women had higher-than-primary education and a higher proportion of control group women were classified as food secure. All intervention- group households participated in the nutrition education workshop, and in three cases, only the husband attended. Dietary data were available from 106 women of the 111 households. Dietary data were not available from two households headed by single men. Data from two lactating women were excluded from analyses. One household was lost to follow-up.

5.4.1 Comparison of nutrition knowledge and practices

There was no significant difference in knowledge or practices between intervention and control groups, pre-intervention (data not shown). Post-intervention, significantly more intervention-group women were aware of and practiced soaking beans, and avoided tea with their meals compared to control-group women (Figure 5.1). As well, significantly more intervention-group women were aware of the benefits of DGLV and OF food consumption compared to the control-group women.

5.4.2 Comparison of women's dietary measures

The proportion of women consuming >15 g of food in each food group was the same for the control- and intervention-groups, pre-intervention, except a higher proportion of control-group women consumed OF (Table 5.2). The proportion of intervention-group women consuming OF increased by 30% compared to their pre-intervention level, and this positive difference was significantly higher ($p<0.01$) than the 10% increase in the proportion of control-group women. Post-intervention, more intervention-group women consumed DGLV compared to control-group women, although this difference was only marginally significant ($p=0.08$). Few women consumed flesh foods, eggs, or organ meats at either time.

Pre-intervention, food and nutrient intakes and diet quality indices were not significantly different between control and intervention groups, except that the intervention-group women had lower zinc intake ($p<0.05$) compared to the control-group women (Table 5.3). Post-intervention, the median intakes (grams) of DGLV and OF were more than 6x higher for intervention group compared to the control group, and the median intakes of 'other fruit and vegetables' for the control group were almost double that of the intervention group; however none of these differences were statistically different. In addition, the intervention-group post-intervention, had significantly lower intake of phytates after intakes were adjusted for the phytate reduction attributed to soaking beans. Most participants (78%) consumed beans the day prior to the 24-hour recall and, prior to accounting for soaking, phytates from beans represented 3 to 95% of phytate intake (median 58%, interquartile range 42% to 74%). These measures were not different between intervention and control groups at either date. Post-intervention, 82% of the intervention group women that consumed beans soaked them, compared with 16% of the control group women.

The differences, pre- to post-intervention, were significant and nutritionally positive for DD, phytate:zinc molar ratio, and intakes of OF and vitamins C for the intervention-group compared to the control-group. The median difference in vitamin A intake was almost five-times higher for the intervention group compared to the control group, although this was not statistically significant (p=0.12).

5.4.3 Multivariable models of dietary measures

The intent of multivariable modelling was to explore whether the results of the nutrition education were dependent on WDL dairy membership status or duration. The relationships between dietary outcomes and other predictors, such as milk production, education, and income, on measures of diet quality were previously reported (Walton et al., 2012), and their potential influence addressed in this trial through the random assignment of women to control and intervention groups. Initial modelling of dietary outcomes found no differences among the four WDL membership duration groups, but that membership status (member vs. non-member) was significant in some cases, instigating the exploration of interactions between membership status and the nutrition intervention on the dietary outcomes.

A membership status-by-intervention status interaction was significant for DD and for intakes of vitamins A and C in linear regression models adjusted for date. The baseline DD (non-members in the control-group) was 4.2 and was lower for the non-members in the intervention-group (3.7) (Table 5.4). By contrast, the DD of WDL members in the control-group was 4.6, and was even higher (4.9) for WDL members in the intervention-group. The median intakes of vitamins A and C for the non-member intervention group were twice that of non-members in the control group, whereas for WDL members, the median intakes for intervention and control groups were similar (Tables 5.5 and 5.6).

5.4.4 Factors influencing daily food choices

Few differences in factors influencing food choices were found between intervention- and control-groups with the exception that health ("know it is good for me") was reported by more intervention-group women (60%) compared to control-group women (25%) ($p \leq 0.05$), and "filling" (ability to satisfy) was cited by fewer intervention-group women (2%) compared to control-group women (11%) ($p \leq 0.05$).

Independent of intervention status, a high proportion of the 110 responding women indicated on-farm availability (63%) and family preference (65%) influenced food choices whereas market availability was important for 10% of women. Women indicated a desire to provide a variety in foods to avoid boredom, and that food was monotonous when only farm produce was available. Examples of desirable variety were ugali (stiff maize porridge), githeri, chapatti, and rice. Money and cooking time were factors for almost 50% of women. A lack of money was reported to limit consumption of meat, greens (seasonally), rice, beans, and chapattis and limit the purchase of fuel for cooking. Similarly, the limitation of time to cook, for 46% of women, was explained as (1) a restricted time available to cook (e.g. if attending a meeting she less time to cook) and (2) limited availability of fuel that restricted choices to foods that cook fast, such as ugali and rice, compared to githeri and chapatti that use a lot of fuel. Few women indicated that land (9%), help (2%), child's age (5%), own age (4%), knowledge to grow food (<1%), knowledge to cook food (2%), or time for farming (4%) factored into food choices.

A large number of women selected for interviews regarding dietary change and attitudes declined the request to be interviewed. As a result, 14 intervention women and four control group women were interviewed using this questionnaire with open-ended questions. All intervention-group women reported changes to food choices, compared with only 25% (n=1) of control-group women, as a result of participating in the study. Intervention-group women reported consuming more DGLV, milk, and fruit, using liquid oil, and trying to follow a more balanced diet, compared to control-group women. One control-group woman reported thinking more about variety and balanced diet but did not report making changes. Intervention- (50%) and control-group (75%) women indicated the desire for more meat or eggs, and more food variety. All those desiring change stated that money restricted their food choices. Fruit trees not growing well in the farm was a second limitation reported, and there was a reported need to buy fruit. During these interviews, intervention-group women reported that soaking beans and maize resulted in softer githeri which allowed women or other family members with sore or missing teeth to consume this food more easily, and that the shorter cooking time for soaked maize and beans used less fuel, although details of fuel use were not investigated in the study.

In interviews that explored the description of fruit and vegetables as something that may be eaten “like they are food”, women revealed that “food” was something that is cooked and heavy, starchy such as ugali or rice, and eaten to fill or satisfy, and that fruit, in particular, seasonally available avocados and mangoes, were sometimes “eaten in excess”, to satisfy hunger, and may replace or augment a meal that was not sufficiently filling. One woman indicated consuming more vegetables (e.g. greens) during the rains due to on-farm availability, but few viewed vegetables as being “filling” or “satisfying”. Two women indicated that fruit and vegetables were less satisfying and therefore not as important as ugali or rice. Several women indicated that they do not buy fruit. During these interviews, nine of the 14 intervention-group women, without prompting, referred to the nutrition education workshop and their knowledge that fruit and vegetables are nutritious and should be eaten throughout the year as part of a balanced diet.

All women interpreted the phrase “eat like you will not eat tomorrow” as overeating or excessive eating. Two themes emerged: 1) overeating at parties or festivals to enjoy variety and special foods that they won’t see for a long time (e.g. chapatti and meat); and 2) overeating at home, at casual work (when a mid-day meal is provided), or at events when household food has been limited (missed meals, inadequate food/not satisfied, when someone has been hungry for so long). Women also commented that for some, eating is a “hobby” and, if food was plentiful, people would eat this way all the time, but that generally it is not economical. Four women remarked that overeating was not good and were concerned about overweight and obesity.

All women believed that WDL members had a more balanced and varied diet. Staple foods on credit from the dairy (12/12 members) and milk money (9/12 members) were the reasons cited by members for better diets. WDL member women reported that access to staple foods on credit allowed them to use their casual job income to buy other food (e.g. fruit, vegetables, tea, sugar, beans, and meat), whereas for non-member women, casual job income must "buy everything". In addition, non-members commented that members "consume milk". More non-members felt WDL membership changed people's diet immediately (50%) compared to members (29%); whereas members (69%) felt the change was 'gradual'.

5.5 Discussion

Our results suggest that the food-based nutrition intervention was successful to enhance knowledge and dietary practices towards improved micronutrient intakes and, with successful randomization, that the positive outcomes were not linked to socio-demographic factors. There was widespread awareness of the practice of soaking beans prior to cooking. A high proportion of intervention-group women, post-intervention, soaked beans which indicated that the education, tasting, and discussions were necessary and effective to change women's practices. As well, success of the intervention was demonstrated in the higher proportion of intervention group women that avoided tea with their meals and had knowledge the benefits of dark green and orange-flesh fruit and vegetables. The significant positive results for DD, proportion of women consuming OF, phytate:zinc molar ratio, and intakes of OF, phytates, and vitamins C and A, and the positive trend in the proportion of the intervention group consuming DGLV, provide further evidence for the success of this nutrition intervention workshop. These results correspond with more intervention-group women considering "health or being good for me" into their food choices.

The positive difference in DD for intervention-group women suggested greater adequacy of micronutrient intakes (Kennedy & Meyers, 2005; Arimond et al., 2010). Evidence for a synergistic effect of WDL membership and the nutrition intervention on DD, suggested that WDL members had a greater capacity to access a variety of foods. This is consistent with members' ability to obtain staple foods on credit from WDL and their reported use of casual income "to buy vegetables" [quote] and corresponds with other observations of a greater success of nutrition interventions when accompanied by economic development activities (Trowbridge et al., 1993) as in this context.

5.5.1 Vitamin A

The higher median intakes of DGLV and OF, and lower intakes of 'other fruit and vegetables' for the intervention group could be explained by a displacement of 'other fruit and vegetables', in response to workshop messages that promoted the consumption of pro-vitamin A rich fruit and vegetables. These results also suggest that the workshop may have enhanced the perception of the value of fruit and vegetables, and challenged the belief that fruit and vegetables are less important than starchy cooked "foods". The positive difference in vitamin A intakes for the intervention-group women was encouraging, although not statistically conclusive. Of particular interest, considering the interaction of the intervention and membership status in the multivariable regression model, was that non-member intervention group women had greater than 2x higher vitamin A (and vitamin C) intakes compared with non-member control group women. This suggested that the non-WDL members had made positive dietary changes, although without increasing their measured dietary diversity, and that the nutrition education intervention was effective to improve dietary practices for all women. This is an important finding, as vitamin A deficiencies are associated with morbidity, mortality and blindness (Underwood & Arthur, 1996), 12 percent of Kenyan women experience symptoms of vitamin A deficiency (FAO, 2005), and our previous research found that 38% of member and 65% of non-member women had inadequate vitamin A intake (Walton et al., accepted for publication). The lower bioavailability of plant-source pro-vitamin A conversion rates (to retinol equivalents), 1:12 for β-carotene and 1:24 for β-cryptoxanthin and ά-carotene (Food and Nutrition Board, 2001), were accounted for in our analyses. However, we were not able to account for other factors, such as fat content of the meal and food matrix, that influence the absorption, bioconversion and bioavailability of pro-vitamin A carotenoids (Weber & Grune, 2012), which may limit the interpretation of the vitamin A intake results. The ability to detect differences in nutrient intakes was limited by the wide range of intakes and high variance associated with a single 24-hour recall.

5.5.2 Iron and zinc

The potential for higher zinc bioavailability in the intervention group's diets is indicated by the widespread adoption of bean soaking prior to cooking by these women, the significantly lower (adjusted) phytate intake, and lower phytate:zinc molar ratios. The soaking adjustment (36% reduction of bean phytates; Shimelis & Rakshit, 2007) reduced the median phytate:zinc molar ratio to below 30, which is associated with 15% zinc bioavailability, compared to 10% bioavailability for molar ratios greater than 30 (Bunch & Murphy, 1997). The post-intervention zinc intake estimates were not corrected for any effect of reduced phytates from bean soaking, which limits our interpretation of the zinc intake data, however, with soaking, some unmeasured increase in zinc absorption is anticipated, given this dose-dependent effect of phytate levels (Davies & Olpin, 1979). Soaking was not sufficient to reduce the molar ratio below 15, as desired for higher (30-35%) zinc bioavailability. Available zinc intake was higher, pre- and post-intervention for the control-group, which may be related to their modestly lower (unadjusted) phytate:zinc molar ratio at both dates.

Bioavailability of non-heme iron was adjusted for vitamin C (ascorbic acid) intake and tea tannins in the meal by the model we used to compute bioavailable intakes. Iron bioavailability was increased from 5% (with <35mg ascorbic acid/1000kcal), to 10% for 35-105 mg ascorbic acid/1000kcal, and to 15% for >105mg ascorbic acid/1000kcal. For each cup of tea consumed with a meal, available iron was reduced by 20%. Despite our findings that more intervention-group women separated tea drinking from food intake by 2 hours (Zijp et al., 2000), and had a higher intakes of vitamin C (Siegenberg et al., 1991), available iron intakes were not statistically different between intervention and control-group women. We were unable, however, to adjust available iron intakes for the effect of a reduction in tannin intakes, from bean soaking, as the nutrient data base did not include tannins, there is variation in the tannin contents depending on growing conditions and bean variety, (Nergiz & Gökgöz, 2007; Bogale & Shimelis, 2009; Shimelis & Rakshit, 2007), and there is no validated model that we are aware of to adjust iron intakes for tannin reductions. This limits our interpretation of available iron intake data, and may have resulted in under-estimated available iron, particularly for the intervention-group. Others have found the fractional absorption of iron and zinc was 49% and 78% greater for individuals consuming phytate-reduced (35 to 63%) maize used in tortillas or polenta (Mendoza et al., 1998; Adams et al., 2002).

Increasing bioavailability of plant-source iron and zinc is important because a high proportion of Kenyan women experiencing deficiencies of iron (56%) and zinc (50%) (UNICEF, 2008). These deficiencies can lead to fatigue, reduced work capacity, and, in cases of severe anemia in pregnant women, may cause fetal growth retardation (low birth weights) and contribute to maternal mortality (Gillespie & Johnston, 1998).

The widespread use of bean soaking, not drinking tea with meals, and higher vitamin C intake is anticipated to improve the absorption of zinc and non-heme iron for the intervention-group households by way of the altered balance between the nutrient intake modifiers and zinc and non-heme iron, although we were not able to quantify these effects. Vitamin A, iron, and zinc are available in abundant amounts and in bioavailable forms from ASF. Low ASF is typical of the Kenya diet in recent history, despite the recognized importance of these foods (Bwibo & Neumann, 2003). Increasing ASF consumption in developing countries is often hampered by high cost, and cultural or religious factors (Gibson & Ferguson, 1998). This was confirmed in our setting as women indicated that money limited their preference to “eat more meat”. A community kitchen intervention successfully increased ASF and iron intake for Peruvian women and girls using low cost organ meats (Creed-Kanashiro et al., 2003). Depending on cultural and other factors, low cost organ meats may represent a possible next-step for these Kenyan women to address low intakes of ASF, and to increase dietary diversity and intakes of vitamin A, iron, and zinc.

5.5.3 Factors influencing food choices

Family preference and on-farm availability were the most prevalent factors influencing the choice of foods that women prepared. On-farm availability may vary seasonally and be vulnerable to drought and therefore limit diet quality. Lack of money factored into the choice of starch foods directly, based on cost, and indirectly, due to fuel requirements for fast and slow cooking foods, and restricted meat, eggs, and fruit consumption. We anticipate that the soaking of beans and maize, with lower cooking time (Martinez-Manrique et al., 2011) and fuel requirement, has the potential for positive benefits in food choices, as well as environmental (fewer trees harvested), and women's quality of life (less wood carrying) benefits, although these outcomes were not examined in this study.

The perception of fruit as something to 'fill you up', and of vegetables as not as important as [starchy] 'food', could impede fruit and vegetable purchases even in higher income situations. The success of the intervention messages to draw attention to the importance of these foods was evident when several intervention-group women referenced the workshop and highlighted that fruit and vegetables are nutritious foods to be eaten throughout the year.

The attitude of "eat like you won't eat tomorrow", reflected eating to excess and concurs with other reports of chronic food insecurity being associated with binge-eating or overeating even when not necessitated by lean times, and which can predispose people to obesity (Tarasuk & Beaton, 1999). Women's overweight status was associated with WDL membership (Walton et al., accepted for publication) and economic development in Kenya (Steyn, et al., 2011). Efforts are needed to address dietary practices and nutrition knowledge to better assure positive outcomes of economic development and improved food security and not a transition to increase risk of diseases associated with over-nutrition.

The sustainability of this nutrition education is not certain, given the limitations in our "information transfer approach" (Allen, 2003) and the recognition that community-based participatory approaches have been more successful (Trowbridge et al., 1993; Creed-Kanashiro et al., 2003; Yeudall et al., 2005). We believe that the economic development work in the community and the longstanding NGO relationship reduced the need for extensive work to gain community participation, which appeared to be the case, given the high level of cooperation and participation. The food-based strategies respected the limited household resources, and promoted strategies that could be adopted with minimal additional financial resources and may contribute to sustainability. Further work to address low DD is needed, and due to the potential complexities of incorporating more ASF, may benefit from a more participatory approach. Babu & Rhoe (2002) suggested the need for sustainable livelihood capacity building and a food systems approach, potentially the production and consumption of small animals (e.g. goats, chickens), with nutrition education to increase ASF consumption.

Our results provide evidence of the positive outcomes from food-based-strategies and support calls to invest in these strategies (Demment, et al., 2003). There is a need to extend the successful strategies to the wider population. One option, to train local women as "champions" and enable these "champs" to teach others, is being investigated with rural Kenyan women (J. Taylor, unpublished). As well, there is a need to support efforts to communicate additional strategies to increase bioavailability, such as flour soaking, fermentation or germination (Gibson & Ferguson, 1998; Gibson, et al., 1998; Hotz & Gibson, 2001), additional food-to-food fortifications (carrots, onion, organic acids) (WHO/FAO, 2004; Gautam et al., 2011). Food composition tables with tannin contents and bioavailability algorithms with iron are both needed in order to account for tannins and tannin reduction on bioavailability. Research to examine and evaluate the sustained use of beneficial food-based strategies is needed.

5.5.4 Study generalizability and limitations

The potential for information sharing between control- and intervention-groups influencing the impact seen from the workshop needs to be considered in the interpretation of the results. The chain-referral method of obtaining the study group utilized the acquaintances of enrolled women to help identify eligible women who could be selected for the study. Therefore, it is conceivable that sharing of information may have happened between acquaintances that happened to be in separate groups. However, there was no evidence to suggest that this was the case.

A second limitation in the interpretation of our results may be random measurement error in our dietary and nutrient data. A four-pass 24-hour recall was used to maximize the food intake recall, and local measures were used to maximize the accuracy of measurements (Kigutha, 1997). Nevertheless, women may deliberately over- or under-report intakes if motivated by pride or seeking aid. This was addressed, in part, by clearly explaining the nature and purpose of the study in advance. Because the women were randomly allocated to the intervention and control groups, women who were predisposed to over- or under-reporting and any other systematic or random error would likely be balanced within the two groups, and should not detract from the importance of the findings.

The small number of women interviewed to examine cultural attitudes may limit broad generalization of these results, but do suggest that gaining an understanding of cultural attitudes may help guide nutrition intervention strategies.

5.6 Conclusion

Our results demonstrated positive effects of the nutrition intervention to strengthen women's capacity as reflected in their nutrition knowledge, practices and attitudes. Specifically, greater awareness of the importance of fruit and vegetables, and higher dietary diversity and fruit and vegetable consumption, for higher vitamin A and C intakes, and the high level of adoption of tannin and phytate reduction practices, in addition to higher vitamin C intakes, to enhance zinc and iron bioavailability. The magnitude of the effect of these strategies on zinc and iron bioavailability was not fully quantified due to limitations in compositional data and adjustment algorithms. Measures of nutrient status may have elucidated the combined effects of the food based strategies, but were not conducted as part of the study as they are difficult and costly, tend to lag behind dietary change, and are influenced by many confounding factors.

Money was reported as the limiting factor for higher meat and egg consumption and, in some circumstances, fruit and vegetables. The potential for bean-soaking to reduce money spent on cooking fuel may help address greater consumption of these nutritious foods and increase dietary diversity although difficult to say without knowing how much each cost.

In addition, there is a need to be aware of and address cultural attitudes toward food and diet as women become more food secure. The perception of fruit and vegetables as only substitutes for [starchy] food when food is scarce may mean that household would not purchase or consume additional fruit and vegetables even when not as restricted by resources.

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Table 5-1. Socio-demographic characteristics (median (25th and 75th) percentile or percent) of control and interventions groups, pre-intervention, among 111 Kenyan farm households

	Control group (n= 56)	Intervention group (n=55)
Woman's age (years)	40 (32,52)	39 (34, 50)
Household size (number of daily inhabitants)	4 (3,5)	4 (3,6)
Number of improved home characteristics	2.5 (2,3.5)	2 (1,3)
Cattle (number)	2 (1,2.5)	2 (1,2)
Asset (number)	2 (2,3)	2 (2,3)
Household food insecurity (access) score	7 (1,12)	9 (2,13)
Woman's education level (with > primary)	25%	32%
Food Secure*	37%	31%
Floor improved	30%	31%

*Household food security categories: secure (secure & mild food insecurity); insecure (moderate and severe food insecurity) (Coates et al., 2007)

Table 5-2. Proportion of women consuming >15 grams of food within nine dietary diversity food groups, pre and post intervention for control and intervention groups among 106 Kenyan farm women

	Pre-intervention			Post-Intervention		
	Control group (n=55)	Intervention group (n=51)	p value	Control group (n=55)	Intervention group (n=51)	p value
Starch/grain	100	100	1.00	100	100	1.00
Legume	78	82	0.63	76	77	1.00
Dairy	100	98	0.48	100	96	0.23
Organ meat	2	2	1.00	0	0	1.00
Egg	7	4	0.68	6	6	0.64
Meat, fish, poultry	11	6	0.49	4	6	0.69
Dark green leafy vegetables	53	49	0.85	46	62	0.08
Orange-flesh fruit and vegetables	36	24a	0.05	46	54b	0.56
Other fruit and vegetables	85	82	0.79	69	69	1.00

a,b proportions comparing the difference pre- and post- intervention for intervention-group significantly different p<0.05

Table 5-3. Women's dietary diversity, micronutrient and food group intakes, and change in intakes, pre- (Aug) and post-intervention (Feb) for control and intervention groups; median (1st and 3rd quartiles), among 106 Kenyan farm women

	Pre-Intervention (August)		p value	Post-Intervention (February)		p value	Difference (post-pre)		p value
	Control (n=55)	Intervention (n=51)		Control (n=55)	Intervention (n=51)		Control (n=55)	Interventio n (n=51)	
Dietary diversity	5 (4,5)	4 (4,5)	0.08	5 (4,5)	5 (4,6)	0.25	0 (-1,0)	0 (0,1)	<0.05
Percent energy from ASF	11 (7,15)	10 (6,17)	0.62	9 (6,16)	8 (4,14)	0.65	-0.93 (-6.1,4.1)	-1.8 (-7.4,3.8)	0.53
Phytate:zinc molar ratio	22 (17,28)	27 (18,33)	0.12	28 (23,34)	26§ (21,31)	0.25	6.1 (-1.2, 11.8)	0.8 (-7.4,8.1)	<0.05
Dark green leafy vegetables (g)	15 (0,81)	14 (0,99)	0.83	5.7 (0,82)	39 (0,100)	0.20	0 (-45,23)	0 (-21,61)	0.42
Orange-flesh fruits and vegetables (g)	0 (0,35)	0 (0, 9.9)	0.26	0 (0,163)	41 (0,207)	0.10	0 (-2.2,82)	29 (0,167)	<0.05
Other fruit and vegetables (g)	103 (36,342)	102 (6,228)	0.83	43 (10,126)	28 (2,83)	0.07	-37 (-231,19)	-38 (-146,0.3)	0.74
Vitamin A (Retinol Equivalents)	820 (374,1168)	531 (245,1254)	0.20	798 (266,1290)	900 (452,1568)	0.19	62 (-422,633)	340 (-188,1128)	0.12
Vitamin C (mg)	89 (59,151)	80 (50,114)	0.24	106 (56,139)	117 (67,153)	0.76	-11 (-49,39)	20 (-20,92)	<0.05
Calcium (mg)	739 (440,1114)	616 (430,932)	0.31	618 (418,808)	511 (332,721)	0.09	-110 (-347,102)	-89 (-386,96)	0.88
Iron (available) (mg) †	1.1 (0.7,1.6)	0.8 (0.6, 1.4)	0.17	1.1 (0.7, 1.5)	0.9‡ (0.5,1.5)	0.21	-0.08 (-0.63,0.34)	-0.11 (-.047,0.40)	0.74
Zinc (available) (mg) †	1.7 (1.2,2.7)	1.3 (0.9, 2.2)	<0.05	1.2 (1.0,1.8)	1.1‡ (0.7,1.4)	<0.05	-0.51 (-1.18,0.45)	-0.24 (1.14,0.12)	0.06
Phytate (mg)	1947 (1117, 3481)	1860 (1149,2527)	0.60	2417 (1472,3567)	1718§ (1109,2734)	<0.05	2.7 (-730,1267)	-47 (-887,654)	0.53

† basal status used for iron and zinc bioavailability estimates

‡ iron and zinc intakes excludes effects of bean soaking (phytate and tannin reduction) on zinc and iron bioavailability

§ phytate intake adjusted for bean soaking

Table 5-4. Women's predicted dietary diversity (mean, 95% confidence interval) from a multivariable linear regression model*, examining a Wakulima Dairy Ltd. (WDL) membership-by-intervention interaction, adjusted for date

	Control group	n	Intervention group	n
Non-members	4.2 (3.6-4.8)	34	3.7(2.7-4.6)	9
WDL members	4.6(3.9-5.2)	128	4.9(3.5-6.3)	44

*R^2adjusted=0.08

Table 5-5. Women's predicted vitamin A intakes (mean, 95% confidence interval) from a multivariable linear regression model*, examining a Wakulima Dairy Ltd. (WDL) membership-by-intervention interaction, adjusted for date

	Control group	n	Intervention group	n
Non-members	323 (225,464)	34	1315 (592, 2920)	9
WDL members	649 (539,783)	128	766 (557, 1053)	44

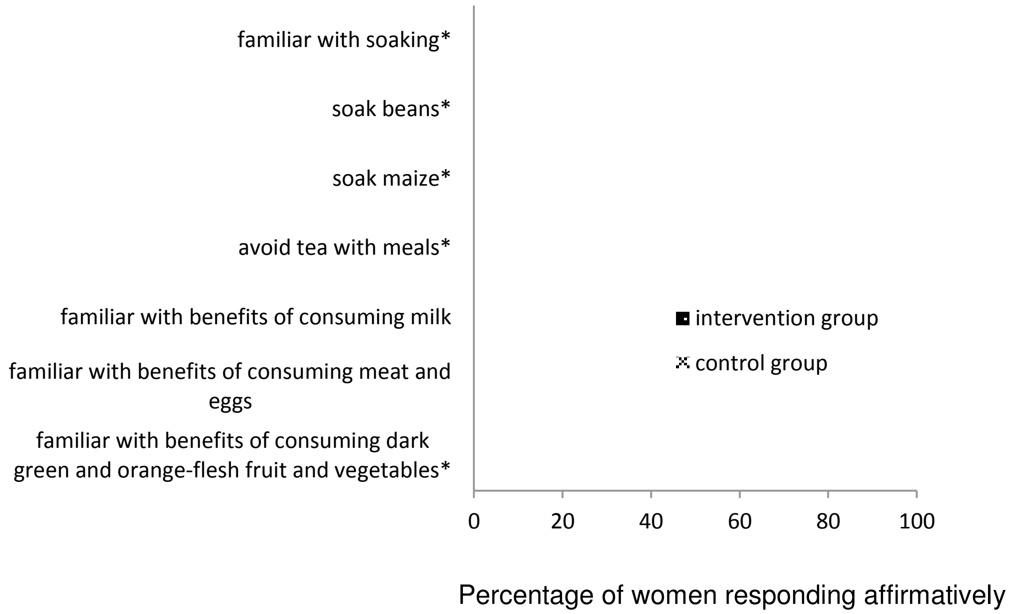
*R^2adjusted=0.07

Table 5-6. Women's predicted vitamin C intakes (mean, 95% confidence interval) from a multivariable linear regression model*, examining a Wakulima Dairy Ltd. (WDL) membership-by-intervention interaction, adjusted for date

	Control group	n	Intervention group	n
Non-members	73(53, 95)	34	128 (79, 187)	9
WDL members	103(91, 116)	128	98(78, 121)	44

*R^2adjusted=0.02

Figure 5-1. Percent of women responding positively to nutrition knowledge and practices in control and intervention women, post-intervention (* significantly different p<0.05)



6 Chapter 6 Summary and general conclusions

6.1 Introduction

This research stemmed from the need for a scientifically rigorous evaluation of the outcomes from a series of development projects that aimed to strengthen dairying capacity and the livelihoods of farmers belonging to a community-based dairy group. These projects were conducted through partnerships with the Wakulima Dairy Ltd. (Kenya), Farmers Helping Farmers (a Canadian non-government-organization), and the Atlantic Veterinary College of the University of Prince Edward Island (Canada) and supported, in part, by the Canadian International Development Agency. The overall hypotheses of this research were (1) that membership, and duration of membership in the Wakulima Dairy Ltd. (WDL), were positively associated with sustainable livelihood assets and outcomes for smallholder Kenyan farm households, and (2) that the effect of nutrition education, on women's nutrition knowledge and practices and women and children's diet quality, was dependent on WDL membership-duration.

Survey results were used to describe, and to examine relationships among, sustainable livelihood assets (human, natural, physical, financial and social capitals) (DFID, 1999) and outcomes (food and nutrition security and income, Chapters 2 and 3) and WDL membership duration. Significant determinants of household food security, and women's nutrition security were identified from sustainable livelihood assets (Chapter 4). A controlled nutrition intervention trial compared nutrition security measures between intervention and control groups, and data was examined for an interaction of the nutrition intervention with WDL membership duration (Chapter 5).

6.2 Duration of community-based group membership and sustainable livelihoods for Kenyan women dairy farmers (Chapter 2)

The specific objective of this study was to identify associations among Sustainable Livelihoods (SL) assets and outcomes and WDL membership status and duration. The SL approach was used to frame this study to examine the main factors (complement of assets and external processes and structures) that affect people's livelihoods and the typical relationships among them (Department for International Development [DFID], 1999). Results were expected to provide evidence for associations of duration of membership with strengthened livelihood assets and outcomes and be useful for NGO's and development partners to guide project design and expectations of measurable outcomes.

The cross-sectional survey of 111 households, evenly distributed across four WDL member groups (1-3, 4-6, 7-9, 10+ years) and one non-members group, was conducted in August 2009. Three questionnaires were used to collect data on SL assets (human capital – e.g. education, household size; natural capital – e.g. access to rented land, main crops; physical capital – e.g. improved housing condition, livestock holdings) and outcomes (food security and income). Associations among the SL assets and outcomes and membership status and duration were assessed using Chi^2 for proportions, ANOVA, or t-tests for continuous normally distributed variables (including transformed variables), and Kruskall-Wallis tests for variables without a normal distribution. Linear and logistic regression models were used to examine trends in outcome measures for an association with WDL membership duration.

WDL members had a stronger complement of human capital (greater proportion with higher-than-primary education, and smaller household size) and social capital (women's group affiliation), but without differences across the WDL member groups. Households with greater-than-three years of WDL membership had larger herds, higher per-cow milk production, more dairy income, and greater food security. Unexpectedly, there were no significant differences in these measures among the longer term (>3 year) member groups. Milk production was low (6 kg/cow/day), even among the longer term members, relative to the maximum production observed among the study group (23 kg/cow/day), and suggests that influences beyond that of WDL membership duration have a role in milk productivity.

There were significant differences among all-members and non-members in measures of physical capital. For example more members had their own latrines and member households were less crowded. Membership duration was associated with a positive trend for improved access to water, improved house conditions, and household food security. Among the WDL members, 80% of women had some or full control of dairy income.

From these findings, it was concluded that a one-to-three year period was needed for households to adopt more intensive dairying and to garner benefits of belonging to the dairy group. This conclusion is consistent with results of a study in Tanzania that found positive production and household outcomes for farmers who had been involved in enhanced dairying for >3 years (Lwelamira, Binamungu, & Njau, 2010). This time period may be significant for development groups and funding agencies for setting realistic goals for short-term projects, and the need, ideally, to pursue medium- to long-term projects in order to have measurable results.

WDL member households had better environments for health and well-being, given their positive measures of physical capital. This situation may result from longer term dairy farming and WDL membership and is indicative of more sustainable livelihoods (Karanja et al., 2010). However, due to the cross-sectional nature of our study, it was not possible to determine causal relationships between SL assets and outcomes and dairy group membership and membership duration. Differences in physical, human, and social capitals among the membership groups provided a basis to assess determinants of food and nutrition security (Chapter 4) while controlling for confounding within statistical models.

Building the dairying skills of women and ensuring their control over income are likely critical factors in the observed positive outcome measures, as income in the hands of women is generally reported to be used for the good of the household compared to men's income which is often used for leisure and men's personal use (Kristjanson et al., 2010). Women are the main operators on smallholder dairy farms in Kenya (Mullins, Wahome, Tsangari, & Maarse, 1996) and Kenyan women traditionally retain some control over dairy income (Tangka, Ouma, & and Staal, 1999). In addition, women were the focus of farm training and efforts were made by the development partners to ensure women retained income control.

6.3 Diet quality with dairy group membership, membership duration, and non-membership for Kenyan farm women and children (Chapter 3)

The specific objective of this study was to identify associations among diet quality measures, of women and children, and WDL membership status and duration. Results were used to provide baseline data for the nutrition intervention (Chapter 5), and to assess the potential benefit of a nutrition education intervention.

The cross-sectional survey, described in Chapter 2, included a 24-hour dietary recall that was used to assess dietary intakes of the mother and one child (age 5 – 14). Food and nutrient intakes were quantified using the World Food Dietary Analysis software, version2, (Bunch & Murphy, 1997) and used to compute (1) milk, food group, and nutrient intakes; (2) prevalence of inadequate intakes (PII) of micronutrient relative to recommendations (Food and Agriculture Organization/World Health Organization, 2001) using the EAR cut-point method, or AI level(Carriquiry, 1999); and (3) diet quality indices associated with adequacy of micronutrient intakes, i.e. dietary diversity (Arimond et al., 2010); percent energy from animal source foods (%ASF)(Allen, 1993); and macronutrient energy distribution (WHO/FAO, 2002). Women's height and weight measurements were used to compute weight status (body mass index).

Associations among diet quality measures and weight status and membership status and duration were assessed using Chi^2 for proportions, ANOVA, or t-tests for continuous normally distributed variables (including transformed variables), and Kruskall-Wallis tests for variables without a normal distribution. Linear regression modeling was used to assess dietary measures with WDL membership duration.

Women's milk intake and lower PII for milk-source micronutrients (riboflavin, vitamin B12, and calcium) were positively associated with longer membership duration. However, few other membership-duration associations were found, and as a result the analyses focused on comparing members to non-members. In addition, fewer children's dietary intakes were collected than expected; therefore, results from boys and girls were combined, and intakes of children of members were compared to non-members. Member women and children had higher milk consumption and %ASF, and lower (72%) energy from carbohydrates, compared with non-members (80%). Member women had higher dietary diversity, and lower PII for seven of 11 micronutrients compared to non-member women. Member children had significantly lower PII for riboflavin, folate, and vitamin B12 of 11 micronutrients examined. Inadequate intakes remained highly prevalent (>45%) for iron, calcium, and vitamin B12 for member women and children, and a substantial proportion of member women (38%) had inadequate vitamin A intake, while member children (39%) had inadequate zinc intake. A significantly higher prevalence of being overweight was found for member women versus non-member women.

The observed positive associations of higher milk consumption, lower percentage of dietary energy from carbohydrates, and lower PII for multiple micronutrients with WDL membership, indicated the potential for improved health and productivity for women and school children. Median milk intake for member children (201g) indicated that at least 50% of member children had the potential for the health, growth, and cognitive benefits associated with the daily consumption of 200 mL of milk (Grillenberger et al., 2006; Murphy, Gewa, Grillenberger, Bwibo, & Neumann, 2007; Neumann & Harris, 1999; Siekmann et al., 2003). These results contrast with other findings of cash-cropping schemes in six developing countries in Africa, Asia and Latin America that demonstrated no short-term positive or adverse nutritional effects (Kennedy, Bouis, & von Braun, 1992). We believe this difference is explained by the choice of milk as the cash-crop, the reliance on consuming home-produced foods, and that milk commonly consumed and is nutrient dense.

It was concluded that micronutrient deficiencies, although reduced among WDL members, were not fully addressed by WDL membership, and that women and children remain at risk of multiple micronutrient deficiencies. In addition, if member women are consuming more tea, as indicated by their higher intake of milk, there may be a concern over the potential negative consequence for women's iron status that can result due to their higher intake of tea-source tannins that bind plant-source non-heme iron since milky tea is the main source of milk in the diet (Zijp, Korver, & Tijburg, 2000). Finally, our results indicated that over-nutrition was associated with dairy group membership for women. This is a point of concern for WDL member women as the transition from under- to over-nutrition is associated higher risk of chronic disease associated with over-nutrition (Popkin, 2002). In summary, there is a need to modify the typical diet of rural Kenyan women and children to address suboptimal nutrient intakes and concerns with over-nutrition to optimize sustainable livelihood outcomes from agricultural interventions. These results provide rationale and a foundation for the nutrition education interventions (Chapter 5).

6.4 Determinants of household food security and women's nutrition security among sustainable livelihood assets of Kenyan dairy group farm women (Chapter 4)

The specific objective of this study was to identify significant determinants of household food security (HFS) and women's nutrition security (diet quality) among SL assets and dairy group membership status and duration. Once identified, these determinants can provide a focus for future food and nutrition security initiatives, with an understanding of their potential impact and synergies. Included was the examination of food security as a determinant of diet quality.

Membership status and duration and SL assets computed from the cross-sectional survey (Chapter 2) were examined as potential predictors of household food security status (a constructed dichotomous variable of secure versus insecure) and of women's nutrition security measures (Chapter 3) in multivariable models. As well, the mean (micronutrient) nutrient adequacy ratio (MAR) (Becquey & Martin-Prevel, 2010; Torheim et al., 2004), was computed for the intake of 11 micronutrients as the mean of the proportion of actual versus recommended nutrient intakes (Arimond et al., 2010; WHO/FAO, 2004), and used as another outcome in multivariable modeling along with %ASF and DD. Transformations (e.g. square root) were applied to some continuous variables, and the normality of transformed outcomes was confirmed using the Shapiro-Wilk's test.

The odds of being food secure were higher among households that had 4-6, 7-9, and 10+ years of dairy group membership (OR 4.6, 5.5 and 8.7) compared to non-members ($p<0.05$), although these odds were not significantly different across the membership duration groups. There were higher odds of HFS with stronger human capital (smaller households, greater-than-primary education for men), social capital (women's group membership), and financial capital (milk production, the number of consumer assets).

Two of the three nutrition security outcomes, percent energy from animal source foods (%ASF) and MAR were univariably predicted by HFS status, in the expected direction, but HFS was retained only in the final model for MAR. In the multivariable models, %ASF was positively associated with milk production (kg/cow/day) and husband's job income (>5000 Ksh/month) and negatively with household size (negatively) ($R^2 = 0.19$), and MAR was associated with milk production, mother's education (> primary), and food secure status ($R^2 = 0.15$). Dietary diversity (DD) was positively associated with women's group membership and negatively associated with women's age ($R^2 = 0.06$).

The finding that higher milk production was positively associated with higher odds of household food security and women's nutrition security measures is important for development practitioners and funding agencies and is most likely dependent on women retaining at least some control over the dairy income (Mullins et al., 1996; Tangka et al., 1999). However, the generally low per-cow milk production (Chapter 2) suggested that influences beyond that of WDL membership duration have a role in milk productivity. With a risk of women losing control over more profitable enterprises (Gladwin, Thomson, Peterson, & Anderson, 2001), it is possible that efforts to increase production, to where it becomes more noticeable, may not be embraced by women although this was not investigated in this study. Alternately, evidence for investment in physical assets may limit resources, including women's income, time and labour, available for enhanced dairy productivity. Our finding support conclusions of Hildebrand (2008), that productivity enhancements in agriculture remain underexploited for improving food security, and that there is a need to identify and alleviate constraints to enhancing production.

Findings suggested that efforts to build and strengthen women's group affiliation may strengthen food and nutrition security outcomes in the short and medium terms. The positive association between HFS and greater-than-primary education, and evidence that access to education is recommended to curb large households (Amaza et al., 2008; Leroy, 2001; Muluken et al., 2008), provides added evidence of the need to support formal education.

Low DD and MAR values indicated micronutrient-deficient diets, even in the presence of HFS. The interpretation of higher values of %ASF was limited, in a nutritional sense, because little animal flesh food or eggs were consumed, and these foods contain important micronutrients not found in milk. These findings highlight the need for additional efforts to increase DD and MAR among rural Kenyan women, even when households are food secure.

6.5 A nutrition education trial among dairy group members and non-members rural Kenyan farm women (Chapter 5)

The objectives of this trial were (1) to evaluate effects of a food-based nutrition education intervention on nutrition knowledge, practices, and specific diet quality indicators of Kenyan dairy farm women, and (2) to examine whether effects of the nutrition intervention were dependent on WDL membership status or duration. A third objective was to explore factors in food choices, and cultural habits and attitudes, to help inform results of the intervention through a better understanding of the reasons behind dietary choices and capacity for dietary changes.

This trial was conducted because the NGO-WDL dairy membership relationship focused on improving dairy management and provided very limited nutrition education. As such, we found in Chapter 2 that WDL membership was associated with higher milk production and better food security. Diet quality findings in Chapter 3 confirmed that WDL member women and children consumed more milk and had a lower prevalence of inadequate intake of some micronutrients, but that the prevalence of inadequate intake of several micronutrients was still high among member (and non-member) women and children, and there was a need to increase dietary diversity. The nutrition education intervention trial was therefore conducted based on the observed need for dietary improvement, and in light of reports that health and nutrition knowledge had a greater impact on child nutrition than food availability (Smith & Haddad, 2002).

The cross-sectional survey, described in Chapter 2, included a 24-hour dietary recall on the mother and one child (age 5 – 14). The same WDL members who participated in the cross-sectional survey were the study population for this trial. The participants (n=111) were randomly assigned to intervention- and control-groups so that half of the WDL members in each duration group and non-member groups participated in a nutrition education workshop. Four nutrition education workshops were held in August 2009 in four different sub-divisions to allow all intervention women an opportunity to attend a workshop in their area.

Each workshop was led by a Kenyan dietitian, with support from a local chef, a Kenyan nutrition research assistant and the Canadian researchers. The workshop promoted the use of food-based strategies to increase iron, zinc and vitamin A intakes. Improving bioavailability of plant-source iron and zinc was addressed through strategies to decrease intakes of anti-nutrients (phytates and tannins) and increase intakes of absorption enhancers - specifically soaking beans to reduce phytates and tannins (Fernandes, Waleska, & Proença, 2010), displacing tea drinking, as a potent source of tannins, from meals (Zijp et al., 2000), and increasing the consumption foods rich in vitamin C with meals(Siegenberg et al., 1991). To increase vitamin A intakes, increasing consumption rich dark green leafy vegetables and orange-red flesh fruit and vegetables, rich in pro-vitamin A, was promoted. Together with the nutrition education presentation, workshop participants had the opportunity to taste foods prepared using the strategies being promoted, and to discuss the foods and preparation methods.

Five months after the workshops, intervention- and control-group women (n=55 and 51, respectively) were interviewed using a 24-hour diet recall and a semi-structured questionnaire to collect data on nutrition knowledge, food intake, and factors in food choices. A sub-sample of women was interviewed, using open-ended questions, to explore cultural attitudes and other factors that may influence food choices.

Pre- and post intervention nutrition knowledge was compared between intervention and control groups, and food and nutrient intakes and diet quality indices (%ASF, DD, MAR) were computed. In addition, phytate:zinc molar ratios were computed based on adjusted phytate intakes (36% decrease) for bean soaking (Shimelis & Rakshit, 2007). Intervention and control group data were compared pre- and post-intervention using $Chi^2$and t-tests. Multivariable modeling was used to examine diet quality outcomes and differences in diet quality for an effect of the intervention and for a possible interaction between the intervention and WDL dairy group membership status and duration. Models were adjusted for potential seasonal effects by including date in the model.

Socioeconomic and food security of the intervention and control groups were not different, indicating successful randomization of these characteristics. Post intervention, significantly more intervention-group women had enhanced nutrition knowledge and used phytate and tannin reduction strategies compared to control-group women. Use of this knowledge and strategies, potentially responses to the intervention, were indicated by higher DD and are expected to improve vitamin A intakes and dietary zinc and iron bioavailability. Efforts to quantify the effects on zinc and iron intakes were limited by available food composition data and algorithms to adjust for the practices. Significantly more intervention-group women than control-group women consumed dark green leafy (DGLV) (62% vs. 46%, respectively) and there was a significant increase in the proportion of intervention group women that consumed orange-flesh fruit and vegetables

(OF) (30% increase vs. 10% increase). A positive change in vitamin A intakes in the intervention group was promising, but not conclusive (p=0.12). Most women were satisfied with their diets, with the exception of wanting more variety, including more fruit, meat and eggs, which were limited due to a lack of money.

From these findings it was concluded that when women were informed of beneficial practices and why they were important, they made positive changes to food preparation and meals that could be expected to improve vitamin A, iron, and zinc intakes in the short-term. WDL members in the intervention group had higher DD potentially a reflection of their strengthened livelihoods as dairy group members whereas intakes of vitamin A and C were higher for non-members in the intervention group. Positive dietary changes in terms of increased dark green leafy vegetables and orange-flesh fruit and vegetables intakes are notable in light of a perception, revealed through interviews, that fruit and vegetables are not as considered to be as important as cooked starch foods. A cultural tendency to eat to excess when food is abundant was identified, and could explain the over-nutrition (high body-mass-index values) results for members (Chapter 3), and raises the concern of increased risk of chronic disease from obesity with more sustainable livelihoods and increased income. Results suggested that additional strategies are needed to increase DD and nutrient density of the diets.

6.6 Linked conclusions

Conclusions from Chapter 2 suggested that the initial 1-3 years of WDL membership represented a transition period after which members had significantly higher dairy farm productivity outcomes (milk production, herd size, milk income) and food security. Neither productivity nor food security outcomes were significantly different with longer membership (4 and more years) although a trend toward higher prevalence of household food security with longer duration was found (Chapter 2 & 4). Members had a stronger, likely pre-existing human capital (formal education) and social capital (women's group affiliation) which may have factored into their capacity to adopt dairying and to enhance farming practices. With more than three years of membership, our findings suggested that members invested in physical assets (consumer assets, water access, latrine, chimney, and hard flooring). These investments may contribute to improved well-being, another of the desirable outcomes of a sustainable livelihood, along with food security.

Results of the 24-hour recall (Chapter 3) found that the 1-3 year members had dietary energy intakes similar to that of longer term members. However food security analyses that considered the previous month revealed a greater need for these 1-3 year members to reduce quality and quantity of food during that longer period (Chapter 2). This need was suggestive of their vulnerability during the pre-harvest (lean period) timing of the interviews, and a recent drought, compared with the longer term members, and this is further evidence of a transition period.

Individual level milk consumption results, in Chapter 3, provided evidence for unequal intra-household distribution of milk consumption, and that member women consumed significantly more milk than member children. To explain this difference, most milk is consumed in tea, and women consume large amounts of tea relative to their children. Fortunately, 50% of the study group member children did consume 200 mL of milk per day, with potential for nutritional benefits from this amount of milk, although 50% of member children consumed less than this amount.

Diet quality analyses in Chapter 3 also found that member women and children had adequate distribution of dietary energy sources, higher DD and %ASF (from milk), and lower prevalence of inadequate micronutrient intakes, compared to non-members. Despite the positive diet quality differences for members, low DD and high prevalences of inadequate micronutrient intake were found. Improved nutrition security for WDL members was expected through the synergy of member's improved household environment (Chapter 2) with their modestly better diet quality. Findings that food security status was not associated with dietary diversity (Chapter 4) indicated that despite consuming more food, the typical diet of women, and likely those in their care, was not different from that of a food insecure women in terms of diversity.

The finding that higher per-cow milk production was positively associated with measures of household food security and women's nutrition security has highlighted the importance of efforts to improve milk productivity. However results in Chapter 2, that dairy group membership duration was not associated with higher milk production beyond a certain median threshold, suggest the need to identify limitations to higher milk production in order to more fully exploit dairy farming to improve food and nutrition security. Considerations of gender roles factoring into limited milk productivity were discussed. Promoting women's groups affiliation, smaller household size, and secondary education for women and men represent potential intervention points to improve food and nutrition security.

The food-based nutrition intervention (Chapter 5) was successful in increasing nutrition knowledge and in changing dietary practices to increase the consumption of pro-vitamin A rich foods and to potentially improve bioavailability of the plant source iron and zinc. The widespread use of bean soaking, not drinking tea with meals, and higher vitamin C consumption was anticipated to improve absorption of zinc and non-heme iron among the intervention-group members although we were unable to quantify these effects due to limitations in methodologies employed. Similarly, a positive difference in vitamin A intakes for the intervention-group women was encouraging, but not conclusive. The positive interaction between intervention and WDL membership status on this group's dietary diversity score was encouraging and suggested that the strengthened dairying capacity of members enabled their adoption of intervention strategies. This interaction was also positive for intakes of vitamin A and C, which is particularly important for the group of non-member women that had a higher prevalence of inadequate intake of these nutrients, pre-intervention, compared to the member women. Adoption of these strategies, while anticipated to have positive nutritional and health benefits, are likely not sufficient for dietary adequacy among women with low DD. Women indicated that money limited their preference to "eat more meat", which is typical of dietary intakes in developing countries, despite the recognized nutritional importance of flesh foods (Gibson & Ferguson, 1998; Bwibo & Neumann, 2003).

6.7 Future research

This cross-sectional research suggested that livelihood assets and outcomes were stronger with WDL membership, and with evidence for a membership duration effect on some of these measures. A longitudinal study with dairy group members would help determine if there is a causal relationship between dairy group membership duration and positive sustainable livelihood assets and outcomes. In light of evidence for positive livelihood outcomes associated with greater-than-three years of WDL membership, research to understand the mix of sustainable livelihood assets required to join a dairy group, such as WDL, is needed to support efforts to address high levels of rural poverty.

There is a need for research to investigate factors limiting higher per-cow milk production. Positive food security and diet quality outcomes were associated with higher milk production however, the median milk production, even after 3 years of WDL membership was relatively low. The role of women as the main dairy farmers, while potentially associated with positive household food security and women's nutrition security, may in fact limit effort to increase milk production beyond a certain threshold, given the potential for higher profit enterprises to be taken over by men (Gladwin et al., 2001). This gender issue may influence uptake of productivity-enhancing education and warrants investigation in future production enhancement efforts.

Effective mechanisms for knowledge exchange are needed to address diet quality in resource-poor settings and research is needed to evaluate sustainability of food-based interventions. Additional compositional data for phytates and tannins and models to account for their reduction on iron and zinc bioavailability are needed to quantify dietary intakes resulting from strategies to increase bioavailability. However, to fully understand effects of strengthened livelihoods outcomes (wellbeing and diet) on nutrition security, data from biochemical tests for zinc, iron, and vitamin A status are needed. In order to address micronutrient deficiencies among women and children, there is need for research to identify and alleviate constraints to higher milk intake (for children) and to higher dietary diversity. Monitoring and addressing the potential for over-nutrition should be part of any agricultural development strategy in order to mitigate higher risks of chronic diseases potentially linked with increased income and food security.

In conclusion, membership in WDL for greater-than-three years is likely, in part, responsible for the observed strengthened sustainable livelihood measures of the members. Good governance, addressing gender, and broad support for members are considered to be important characteristics of WDL relative to these positive observations. Higher milk consumption was positively associated with WDL membership for women and children and improved the adequacy of their micronutrient intakes. However, there was a need to modify the typical diet which was, in part, addressed through the nutrition intervention. Women made modest dietary changes when informed. Better nutrition security of the greater-than-three year members was anticipated because of the synergy between their physical assets, indicative of better well-being, and better diet quality. In addition, our findings demonstrate the benefit of investment in nutrition education with agricultural projects, positive influences of secondary education for men and women, a need to curb large households, and to enable women to participate in social-support groups for greater food and nutrition security.

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7 APPENDICES

7.1 APPENDIX A Service Utilization and Quality of Life Survey

	Farm ID
Family and mothers name	Date & time
Interviewees' name, relationship, if not mother	Interviewers:

Confirmation of invitation questions	**Aug. Seminar:**	**No**	**Yes**
Are you or your husband on the Wakulima board of directors?		0 – no	1 – yes
Since joining WDL have you been a non-member for more than 6 months?		0 – no	1 – yes

Household demographic how many yrs a member_____

Who is the household head?

How many people live in this household > 5 days per week?					
Name /age /relation	no formal	primary	secondary	College	Univ.
Marital status	single	sep'ted/div	widowed	married	

What is the ownership of this house 1-owned 2-leased 3–other (describe)

How many acres does your family own	<1	1 – 2	2 – 5	>5
Do you rent additional land to farm		0 – no	1 – yes	___acres
Who cares/oversees the feeding and milks the cow?				
cows milking now/ how many?	0 – no			
dry cows / how many?	0 – no			
heifer calves / How many ?	0 – no			
bull calves / how many?	0 – no			
How many times milking ___/day; what are the uses:	1st	2nd	3rd	
Home (serving how many people)				
Wakulima				
sell direct to person				
other (describe)				

Of services provide by the dairy; which have you used and if used, how beneficial?

	0 not used not rec'd	1 not useful	2 useful/how
Credit			
Loan to buy cow			
Mobile banking service			
AI from Wakulima			
Veterinarian services			
Laboratory testing			
Teat dip Mastrite program			Using now? No Yes
Did you attended any training seminars held by Wakulima? if so, how useful?			
Feeding your cow and calf (steaming up, raising calf)			
Factsheet			
How to avoid rejected milk (milk quality)			
Factsheet			
How to keep your dairy cows/calves healthy (lameness, parasites)			
Factsheet			
Growing feeds and silage making			

(Bernard)			
Factsheet			
Reproduction – AI, detecting heat			
Factsheet			

Household characteristics, income, assets

HC 1. How many buildings on property? ___

HC 2. How many rooms in main building? ___

HC 3. Do you have a latrine? 0-No
1-Yes

HC 4. Is latrine on own property? 0-No 1-Yes

HC 5. If no to 4, is latrine at neighbor's? 0-No
1-Yes

HC 6. Type of latrine 1-Pit 2-Flush 3-Bucket 4-Other

HC. 7 Dry season primary source of water

1-Piped to compound	2-Piped to neighbors	3-Rainwater in tank
4-River/stream	5-Borehole	6-Spring
7-Public tap	8-Other	

HC 8. Wet season primary source of water

1-Piped to compound	2-Piped to neighbors	3-Rainwater in tank
4-River/stream	5-Borehole	6-Spring
7-Public tap	8-Other	

HC 9. Primary fuel source

1-Charcoal	2-Firewood	3-Natural gas
4-Kerosene	5-Electric	6-Other

HC 10. Primary source of lighting

1-None	2-Kerosene	3-Electric
4-Solar	5-Other	

HC 11. If charcoal or wood, does stove/oven have a:

1-Chimney	2-Hood	3-Vented ceiling
4-No vent system	5-Other	

OBSERVATIONS

Obs 1. Material for walls of main house

1-Brick/cement	2-Wooden planks	3-Unfinished wooden poles
4-Mud/dirt	5-Other	

Obs 2. Material of flooring in main house

1-Brick/cement	2-Wooden planks	3-Tiles/carpet
4-Mud/dirt/dung/sand	5-Other	

Obs 3. Material for roofing on main house

1-Brick/cement	2-Wooden planks	3-Unfinished wooden poles
4-Tin cans	5-Corrugated metal	6-Straw/grass/makuti
7-Tiles	8-Other	

Obs 4. State of dwelling

1-Completely dilapidated shack	2-Needs no repairs or minor repairs
3-Being repaired now	4-Under construction

How do you communicate with friends or relative in Nairobi or other location?

Mobile phone	0 – no	1 – yes

How do you travel to the market or milk collection point?

Bicycle	0 – no	1 – yes
motorcycle	0 – no	1 – yes
car/truck	0 – no	1 – yes

If you want information from the outside world, how do you get it?

Television	0 – no	1 – yes
Radio	0 – no	1 – yes

When you have leftover food, how will you store it?

Refrigerator	0 – no	1 – yes

Do you sell vegetables, fruit, eggs, chickens etc. from your shamba		0 – no	1 – yes	77 – refused
if yes, average Monthly income from these sales	<1000 Ksh	1,000 - 5,000	>5,000	

Do you sell coffee?		0 – no	1 – yes	
if yes, what was your 2008 gross income? Approx.				77 – refused

Do you have a job/business/other income (pension) besides shamba		0 – no	1 – yes	
If yes, describe:				
average monthly income from this:	<5000	5000 to 10000	>10,000	77 – refused

Do your husband have a job/business/income (pension) besides shamba?		0 – no	1 – yes	not Applic.
If yes, describe:				
average monthly income from this:	<5000	5000 to 10000	>10,000	77 – refused

Monthly income from selling milk	<5000	5000 to 10000	>10,000	77 – refused
** permission to obtain gross milk revenue for 2008 from WDL*	0 – no	1 – yes		77 – refused

*all values in Kenyan Shillings Ksh

Name your three main crops by land area		Cash crop	Home use	Farm use (cow feed)
1				
2				
3				

What sources of credit do you use: WakSacco Bank merrygoround other(describe)

Are you a member of a: church school womens group other?

Hold office in any? No Yes _____________

7.2 APPENDIX B Dietary knowledge and practices

Nutrition knowledge

In your opinion why do you eat fruits and leafy greens (e.g. Sukuma, terere) and pumpkin, carrots, (orange veg) (2 reasons)

In your opinion why do you eat meats and eggs? (2 reasons)

In your opinion why do you consume milk? (2 reasons)

Do you soak maize before cooking?	0-no	1-yes
Do you soak beans before cooking?	0-no	1-yes
Are you familiar with either of these preparation methods or why they would be used?		
Do you drink tea or coffee with your meal/food?	0-no	1-yes

7.3 Appendix C Household food security (access) questionnaire

FarmID
Date

Questions about the state of food in your house...

FS 1. In the past month, were you scared that your household would not have enough food?

nuclear household considered.

include others living in home (helpers?)

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 2. In the past month, were you or any household members not able to eat the kinds of food you prefer because of lack of resources?

chicken makimo, chapati, beef makimo

lack of resource – money, physical means

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 3. In the past month, did you or any household members have to eat a limited variety of foods due to a lack of resources?

that is a monotonous diet without tomato,

rice, ugali,

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 4. In the past month, did you or any other household members have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food

less preferred e.g. Small dried fish, fish

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 5. In the past month, did you or any household members have to eat a smaller meal than you felt you needed because there was not enough food?

Meal meaning Breakfast, lunch, supper

smaller, referring to quantity

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 6. In the past months, did you or any other household members have to eat fewer meals in a day

because there was not enough food?

skip meal to not go to bed hungry?

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 7. In the past month, was there ever no food to eat of any kind in your household because of lack

Of resources/money to get food?

not usual level of reserves / no food at all

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 8. In the past month, did you or any household member go to sleep at night hungry because there was not enough food?

e.g. children fed, but adults miss meal(s), starving

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

FS 9. In the past month, did you or any household member go a whole day and night without eating anything because there was not enough food?

meaning eating very little or only porridge

Due to a lack of resources; less related to *appetite*

Never	0
Rarely (once or twice in the past four weeks)	1
Sometimes (three to ten times in the past 4 weeks)	2
Often (more than ten times in the past four weeks)	3

7.4 Appendix D 24-hour dietary recall

1st pass: **list everything you ate and drank yesterday including alcohol and sweet**

Date:

(probe: salt, fat, milk, vegetables, fruit, sauces, relishes, stew)

Interviewers:

2nd pass: how much did she eat / serving any leftover?

Interviewee:

3rd pass: Recipe details - ingredients, amounts, cooking method

height

is salt used/iodized, is solid or liquid fat used, is it Vit Afortified

weight

Review list… anything missing?

Time/location	Food	portion / leftover		Recipe: ingredients,amount	FOOD SOURCE S - shamba M – market O – other (describe)	
				recipe total volume		
				recipe total volume		
				recipe total volume		
out of home snack, meal,						
Any vitamins or mineral tablets : (what, Brand, how often)						
* are the foods listed representative of a typical day? yes no - not typical explain: (feast, festival, ill, market day)						

7.5 APPENDIX E Cultural food factors inquiry questionnaire

Name	
Date & time:	
Interviewers:	

---

1. What factors influence the choice of foods you and your family eat each day? *(circle & add others)*
    a. Resources: time to gather or prepare or cook, money, cooking fuel, land to grow, irrigation, water, help for home and farm work (children, hired etc
    b. Knowledge: how to cook, how to grow,
    c. Health: specific disease/condition, 'know it is good for me', sore teeth, age
    d. Family preference: filling/satisfying, like/dislike, husband-other member choice
    e. Availability (local market, on farm)
    f. Other

7.6 Appendix F Effects of the study participation: (post-intervention, sub-sample of participants)

1. Now we are going to ask a few questions about food related changes you may have made in the time since we last met and your attitude toward food (request OK to audio record)

    a. Did your participation in this study cause you to make changes to: **
        i. the foods you are eating? No Yes if yes: What & why? Easy? Continue?
        ii. The soaking of maize and/or beans before cooking? No Yes Why? Easy? Continue?
        iii. The drinking of tea with meals/food? No Yes Why? Easy? Continue?

***interviewer – For each 'no' in 'a' move to 'b' & 'c' below to query about changes desired but not made and reasons why not making the change*

b. Are there any changes you would like to make?
Choices
Soaking
Tea
Other?

c. Describe any challenges to making the(se) change(s).
Choices
Soaking
Tea
Other?

2. Finally we want to ask you about some phrases that we have heard and 1) if you are familiar with them 2) what it means to you and 3) how it influences what and how much you eat. *(ask each Q 1 -3 for each of questions a and b)*

    a. Concerning fruits and vegetables "we eat them like they are food"?

    b. "eat like you will not eat tomorrow"?

3. Do you feel being a member of the Wakulima Dairy changes what people eat? Why or why not? If yes, how? How quickly?

D. Confirm identity, Income control & intervention status (*added; all participants; final step of post-intervention interview)*

1. confirm dairy account number (Farm ID) ____________________

2. In whose name is the dairy membership account (Husband, Wife, both, unsure) Why? Since when?

3. In your home, when food is purchased, who usually does the buying? (Husband, Wife, both)? Why? Since when?

4. Who in the family controls the dairy income? (Husband, Wife, both)? Why? Since when?

5. Did you attend one of our nutrition seminars held in August? Yes no unsure

7.7 APPENDIX G Agenda for nutrition workshop

WDL Board member – welcome, prayer, introductions

Hilda Macharia – The Kenyan food pyramid, Balanced diet, need for fruit and vegetables, in partudluar lark green and orange flesh fruit and vegetales for vitamin A; to help eyesight and immunity, importance of not drinking tea with meal; presenting water or 'nyroni' (hot milk, water, ans sugar as options)

Francis (chef) and Colleen serve samples

Tasting – githeri from soaked beans and dry maize, with multiple dark green leafy veg

Chapatti prepared with mashed pumpkin/squash

Samwel – 'did you like the food…' discuss recipes and preparation dierctions of soaking; note that we did not serve tea!

Samwel - Presentation of nutrition sheets, oil (noting vitamin A) seeds for indegenouse leafy greens (drought tolerant), growing direction for seeds

Colleen – thankyou to everyone for participating (Samwel to translate)

WDL board member – thankyou to participants and presenters; closing

7.8 APPENDIX H Nutrition fact sheet for workshop (English version)

The truth is

Eating well prevents diseases, develops strong bones and helps students get good grades.

Fact #1 Eating fruits and vegetables throughout each day helps the body fight diseases.

Fact #2 Soaking githeri before cooking and not taking food together with tea enables the body to use food's nutrients better

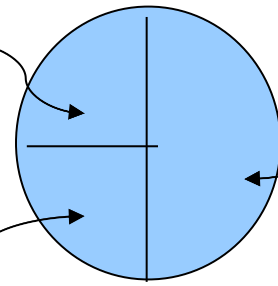
Fact #3 Porridge should be fed to children only after six months exclusive breastfeeding and be a mixture of mostly maize with some sorghum, millet

Fact #4 Eating food from animal origin like liver, meat, eggs and milk enhances children's learning abilities and provide vital nutrients and energy

Food servings for all people

Energy giving foods – ugali, rice, potatoes. (1/4 of plate)

Body building foods – beans, green grams, meat. (1/4 of plate)



Protective foods – kales, amaranthus, carrots, tomatoes. (1/2 plate)

Drink Naironi or water (not tea) with your meal!

People's food needs depend on their age and how physically hard they are working. Make sure that you eat a mixture of preventive foods, body building, and energy foods every day.

Milk servings per day

Years	Serving per day (1 cup = 2/3 of a '15')
Children less than 9 years	2 or 3 cups
Children between ages 9- 12	3 cups
Children between ages 13 - 19	4 cups
Adults – 19 years and above	2 cups

Different cooking methods to help your family

Githeri

Soak the maize & beans in water overnight. After soaking, the githeri cooks faster, is more nutritious and reduces stomach problems.

Fried kale

Fry onion and tomatoes in cooking oil; for each person use a small spoon of oil. Add amaranthus, kales, spinach, or any other green vegetable. Cook until ready. Cook for a short time to conserve the vitamins.

Ugali cooked with milk (this will make up part of the milk servings needed for the day)

Prepare with equal amounts of water and milk
Put milk and water in a sufuria and boil.
Add flour as you mix until stiff enough.
Cook ugali until ready.

Milk porridge

Prepare with equal amounts of water and milk and sugar (if desired)
Boil milk and water together in a sufuria.
Mix the flour and little water then put in a sufuria.
Continue mixing until a thick consistency.
When cooked add sugar.

Porridge can be taken with sweet potatoes, arrow roots and yams.

Secrets to great health

Vitamin A

Green leafy vegetables (kales, amaranthus, pumpkin leaves, nettle leaves) and yellow fruits (pawpaw, mangoes, pumpkins and carrots) are good sources of Vitamin A. Cabbage is less good. Vitamin A protect the body from diseases and aids in keeping good eye sight.

Factors interfering with nutrients entering your body.

Tea, coffee and unsoaked beans contain substances that interfere with food digestion and utilization of vitamins and minerals.

Soaking beans for 12 hours before cooking helps remove these substances. This improves your body's ability to use essential minerals like iron, zinc, and calcium in the food.

It’s recommended to take tea two hours before or after meal to avoid combining the anti-nutrients and your meal. This way the food will have been digested and the nutrients absorbed before you take your tea.

Diets for infants and children six months and above.

An infant should be fed exclusively on breast milk for 6 months, with no other food or even water. Breast milk is not enough after six months; therefore supplementary food is acceptable as the child continues to breast feed. These foods include porridge with milk and sieved fruits. The porridge flour should be made from a mixture of 2 kilograms of maize and 2 kilograms mixture of (sorghum, millet and others). Preparing the porridge with milk will further help the baby grow well and develop good learning capabilities. Feeding sieved fruit (e.g. ripe pawpaw) provides important vitamins and minerals.

Food from animal sources

Liver, meat, eggs and milk help build the body as they contain minerals iron, zinc, and other essential vitamins and nutrients that improves understanding and prevent the child from diseases.

Fruits

Fruits like mangoes, pawpaw, passion fruits, guavas and lunguads contain Vitamin C. When eaten with a meal will help the body to better use minerals (iron and zinc) in the food. Fruits have many other vitamins and important nutrients and therefore eating everyday is important.

Calcium and bone development

Milk without tea leaves provides essential calcium to help people, especially women and children grow and remain strong and healthy. Children ages 18 and below need calcium for height and bone development. Two servings of milk is essential. Women should take two servings of milk, without tea leaves, per day to help in breast feeding and maintaining strong bones.

Breakfast

Everyone should eat breakfast before going to school or to the garden or other work. Eating ugali, arrow roots, sweet potatoes, chapatti or any other foods including fruits and vegetables, and with milk, is good morning eating.

Sugar

Limit sugar in tea to on small spoon. Too much sugar contributes to diseases like increased pulse rate and diabetes).

Oil

Use liquid oil rather than solid fat in cooking to keep your heart and blood healthy

Compiled by: Farmers helping Farmers, Wakulima Dairy Ltd, University of Prince Edward, Egerton University and nutritionists (Colleen Walton, Samwel Mbugua, and Hilda Macharia) and funds from the Canadian Home Economics Foundation. (A Kikuyu version was also prepared and available)